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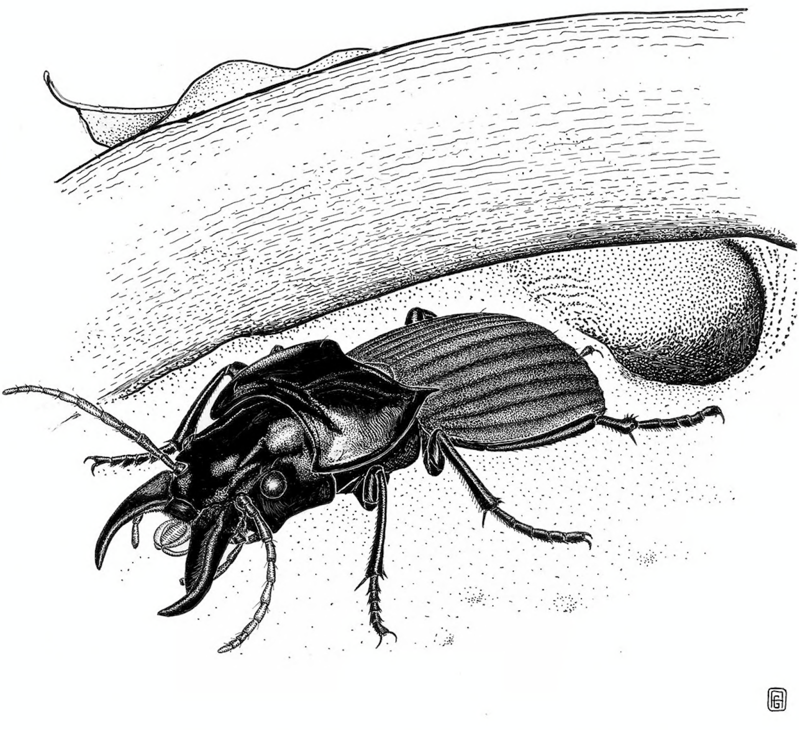

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COVER

The giant wingless carabid, *Nurus rex* Darlington 1961, at the entrance to its burrow under a rainforest tree root. The species occurs only in a small cap of rainforest on the summit of the 1000 m Mt Elliot, just south of Townsville, and was first collected by the noted Harvard biogeographer, Philip Darlington, when he made the first entomological ascent of the mountain in March 1958. It is the largest and most northerly of about a dozen species in its genus, all of which are now known to live in burrows with a cleared entrance court where they ambush passing invertebrates at night. Pen and ink drawing by Caloundra ESQ member, Dr Albert Orr, whose illustrated books on dragonflies and butterflies have won awards in Australia and overseas.

A NEW SPECIES OF *GYNOPLISTIA* WESTWOOD CRANEFLY (DIPTERA: LIMONIIDAE) FROM AUSTRALIA

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Abstract

A new species of Australian cranefly, *Gynoplistia* (*Gynoplistia*) *reidi* sp. n., is described from Victoria and placed in the *zebrata* species-group.

Introduction

The Australian species of *Gynoplistia* Westwood were revised by Theischinger (1993), with additional species described in subsequent papers (Theischinger 1994, 1999, 2000). This paper further adds to the knowledge of the Australian fauna by the addition of one new species to the *Gynoplistia* (*Gynoplistia*) *zebrata* group of Theischinger (1993).

The species described herein was discovered during surveys of the cranefly fauna of Victoria undertaken by the first author.

Materials and methods

Specimens were collected by sweeping a hand net through vegetation and then preserved in 100% ethanol. As a result of this preservation, the coloration of specimens might have changed from the natural state. The illustrations of the male genitalia (hypopygium) are from specimens cleared in KOH and displayed in glycerol. Descriptive terminology is in accord with McAlpine (1981) and Alexander and Byers (1981).

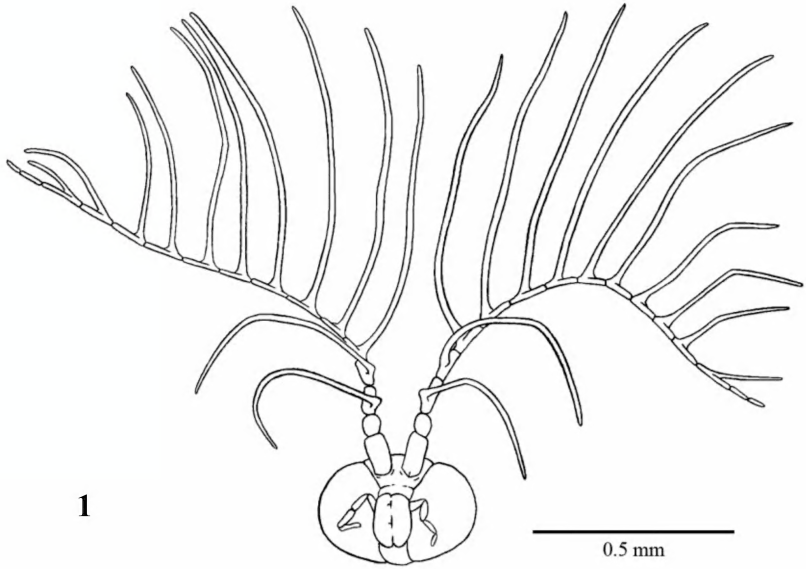
Abbreviations as used in figures and description: *A1*, first anal vein; *a1*, first anal cell; *A2*, second anal vein; *a2*, second anal cell; *ae*, aedeagus; *apm*, anepimeron; *ast*, anepisternum; *bm*, basal medial cell; *bscu*, basal deflection of the first anterior branch of the cubitus vein (CuA1); *cc*, costal cell; *crv*, cervical sclerite; *cup*, posterior cubital cell; *dm*, discal cell; *ge*, gonocoxite; *ig*, inner gonostylus; *ile*, inner lateral element of aedeagal complex; *kpm*, katepimeron; *kst*, katepisternum; *ltg*, laterotergite; *M1+2*, fused first and second posterior branches of the media vein; *M3*, third posterior branch of the media vein; *MA*, anterior branch of media vein; *mem*, metepimeron; *mer*, meron; *mst*, metepisternum; *mtg*, mediotergite; *mvp*, medio-ventral process of gonocoxite; *og*, outer gonostylus; *ole*, outer lateral element of aedeagal complex; *presct*, prescutum; *prpl*, propleuron; *pst*, pterostigma; *r-m*, radial-medial crossvein; *Rs*, radial sector vein; *scc*, subcostal cell; *sct*, scutum; *sctl*, scutellum; *t9*, tergite 9.

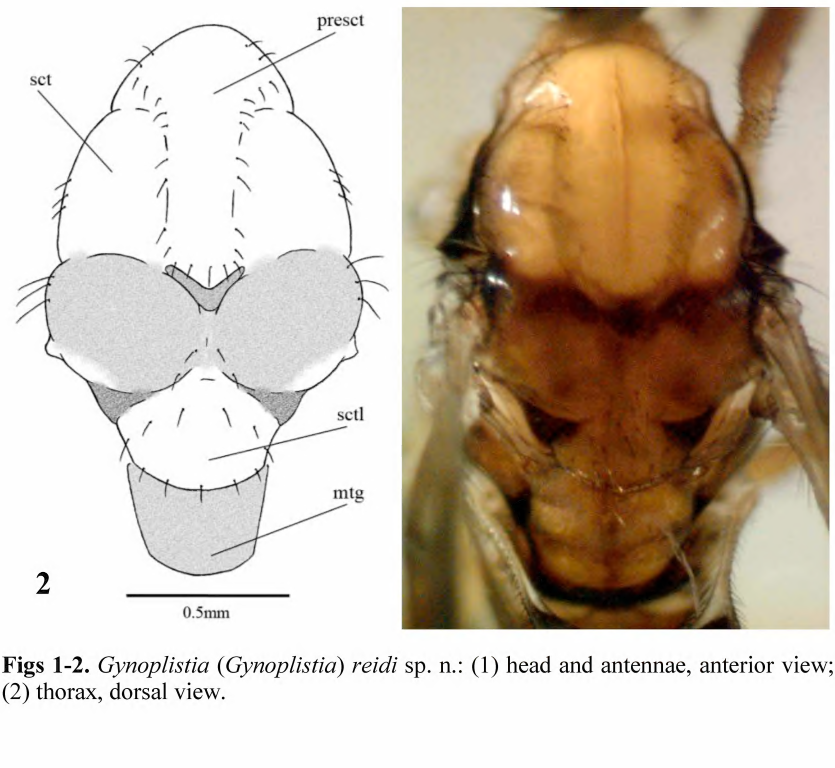
***Gynoplistia* (*Gynoplistia*) *reidi* sp. n.**

(Figs 1-7)

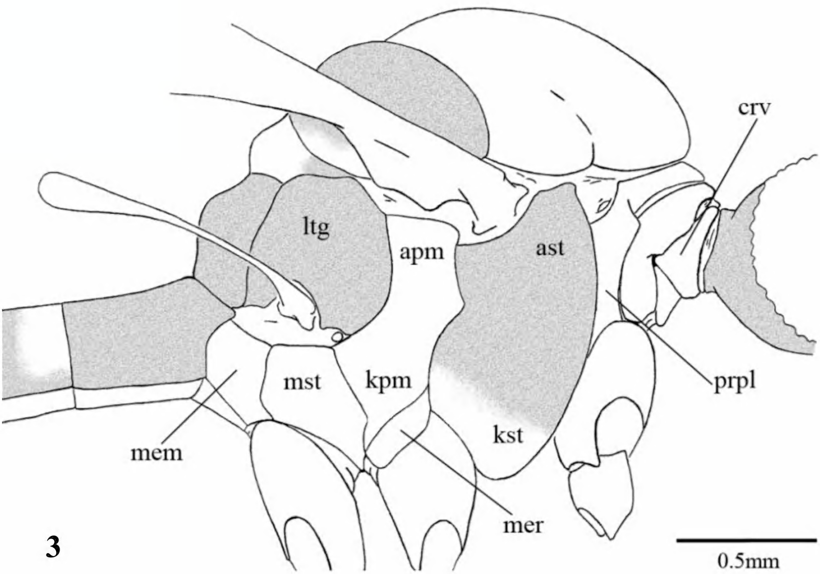
Material examined. Holotype ♂, AUSTRALIA (VICTORIA): Ada along Latrobe River by Latrobe River campground (-37.880964°, 145.889509°), 17/01/2016, Z. Billingham; in Museum Victoria collection (MVT22108). *Paratype* ♂, Powelltown, along Little Yarra River (-37.86017°, 145.74446°), 6/01/2013, Z. Billingham; in Museum Victoria collection (MVT21937).

Description. From holotype male, female not known. Head dark brownish black; mouthparts greyish brown. Antenna (Fig. 1) 16 segmented, pectinate; basal two flagellomeres bearing mesoventrally directed extensions, following 10 flagellomeres bearing dorsally directed extensions, final two flagellomeres lacking extensions; scape, pedicel and basal two flagellomeres, except for the extensions, yellowish brown, otherwise blackish brown. Pronotum yellowish brown dorsally. Prescutum yellowish brown. Scutum yellowish brown to the transverse suture, dark brown beyond this point, posterolateral angle yellowish brown. Scutellum yellowish brown. Mediotergite brown (Fig. 2). Cervical sclerite and propleuron yellowish brown. Anepisternum brown, katepisternum brown dorsally, yellowish brown basally. Anepimeron, katepimeron and meron yellowish brown. Laterotergite brown. Metepisternum and metepimeron yellowish brown (Fig. 3). Coxae and trochanters brownish yellow; femora with proximal 1/3 brownish yellow, middle 1/3 dark brown and distal 1/3 brownish yellow interrupted by a subterminal dark brown ring; tibiae with narrow proximal brownish yellow ring, tibia 1 and 2 with middle 1/3 brownish yellow, otherwise brownish black, tibia 3 with middle 1/3 white, remainder brownish black; tarsi dark brownish black (Fig. 4). Wing (Fig. 5) 6.0 mm, with extensive grey pattern; costal and subcostal cells grey; pterostigma darker grey; apex and posterior margin infuscated, apex especially so; three darker grey bands present: one beginning just distal to vein MA and extending into cells bm and cup, one at origin of Rs extending through cells bm and cup and crossing A1 at 2/3 its length to terminate in cell a1, and one at the fork of Rs extending along r-m and base of M1+2; further grey markings at the distal end of dm, along bscu and at 1/2 the length of A2 in near alignment with the aforementioned dark band originating distal to MA. Halter with stem brownish yellow, knob darker brownish. Tergites 1 and 8-9 entirely dark blackish brown, tergites 2-7 with basal brownish yellow band. Sternites showing similar pattern with more extensive basal brownish yellow bands. Hypopygium (Figs 6-7) with hind margin of segment 9 dorsally widely rounded (convex), ventrally with wide, deep V- to U-shaped excision. Gonocoxite brownish yellow with medioventral, thumb-shaped, backward-directed, setose process. Outer gonostylus widely curved with apex pointed; inner gonostylus S-curved with apex rounded. Aedeagal complex with two lateral elements, the outer short dorsad-directed and sickle-shaped, the inner backward-directed, long and sinuous, and a short broad-shouldered medial element (aedeagus).





Figs 1-2. *Gynoplistia* (*Gynoplistia*) *reidi* sp. n.: (1) head and antennae, anterior view; (2) thorax, dorsal view.



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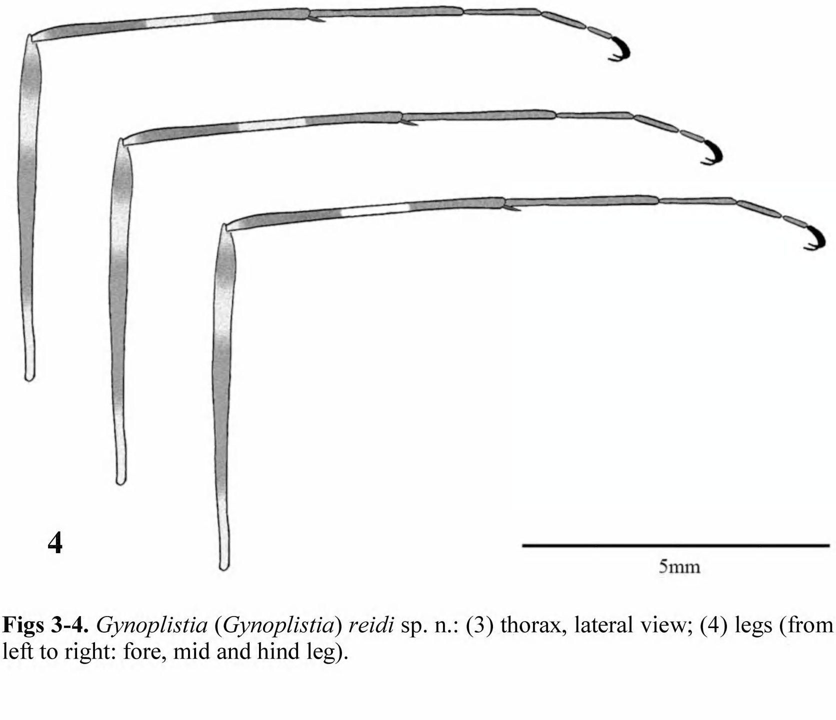

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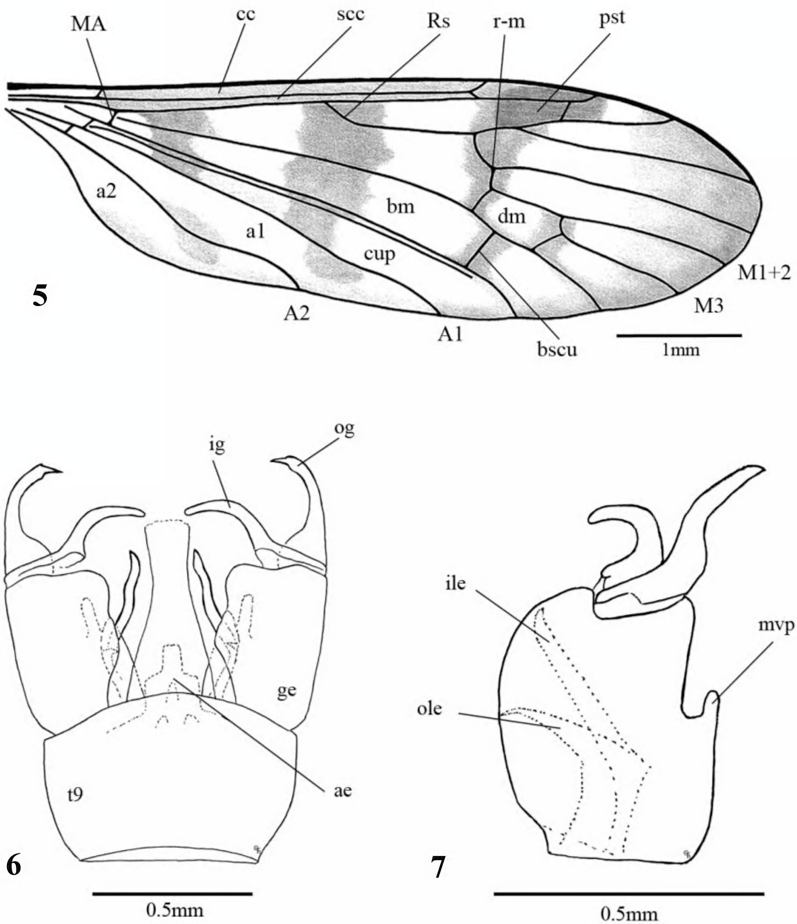
Figs 3-4. *Gynoplistia* (*Gynoplistia*) *reidi* sp. n.: (3) thorax, lateral view; (4) legs (from left to right: fore, mid and hind leg).



Figs 5-7. *Gynoplistia* (*Gynoplistia*) *reidi* sp. n.: (5) wing; (6-7) hypopygium, dorsal (6) and lateral (7) views showing lateral elements of aedeagal complex (stippled).

The paratype male is freshly emerged from the pupa and as a result some features of its coloration differ from the holotype, most notably the abdominal banding and patterning of the legs, which are much less evident in the paratype. The features of the paratype hypopygium agree with those of the holotype.

Discussion. Thoracic colour pattern and details of segment 9, gonocoxite, gonostyli and aedeagal complex indicate that *G.* (*G.*) *reidi* sp. n. is a member of the *G.* (*G.*) *zebrata* group of Theischinger (1993), which includes *G.* (*G.*) *zebrata* Alexander, *G.* (*G.*) *quagga* Theischinger, *G.* (*G.*) *yarra* Theischinger

and *G.* (*G.*) *tooronga* Theischinger. The presence of a backward-directed, thumb-shaped, setose, medioventral process on the gonocoxite, the widely rounded posterior margin of dorsum of segment 9 and the prominent long sinuous inner and the short curved outer lateral element of the aedeagal complex are diagnostic for *G.* (*G.*) *reidi* sp. n. Potential presence of the backward-directed, thumb-shaped, setose, medioventral process on the gonocoxites has to be included in the diagnosis of the *Gynoplistia* (*Gynoplistia*) *zebrata* group of species.

Etymology. This species is named in reference to the historic Reid's sawmill site, located near the type locality.

Acknowledgements

Specimens collected from protected areas were done so under Vic DEPI permit number 10006838.

The first author wishes to thank Ros StClair (EPA Victoria) and Dr Ivor Growns (NSW Office of Water) for their guidance and assistance. Gutteridge, Haskins & Davey (GHD Pty Ltd) water sciences team are also thanked for their support of the first author's studies.

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A NEW SPECIES OF STALK-EYED *ACHIAS* FABRICIUS (DIPTERA: PLATYSTOMATIDAE) FROM FERGUSSON ISLAND, PAPUA NEW GUINEA

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Abstract

Achias tennenti sp. n. is described from Fergusson Island, D'Entrecasteaux group, Papua New Guinea. A key to the six species recorded from Milne Bay Province is included.

Introduction

Achias Fabricius is one of the largest genera of Platystomatidae known from the Australasian Region, with 100 species recorded by McAlpine (1994) and many more expected to occur. The genus is restricted to New Guinea and neighbouring islands plus Melville Island and NE Queensland in northern Australia. Recent collecting by John Tennent in the D'Entrecasteaux group, Milne Bay Province, Papua New Guinea, has revealed a new species from Fergusson Island that is described below. Morphological terminology largely follows White *et al.* (1999).

Achias tennenti sp. n.

(Figs 1-4)

Type material. *Holotype* ♂, PAPUA NEW GUINEA: Milne Bay Province, D'Entrecasteaux group, Fergusson Island, 'Oiatabu (Mount Kilkerran) summit, 1804 m, 6th October 2016, John Tennent (in Natural History Museum, London). *Paratypes*: 2 ♂♂, same data as holotype (in Natural History Museum, London).

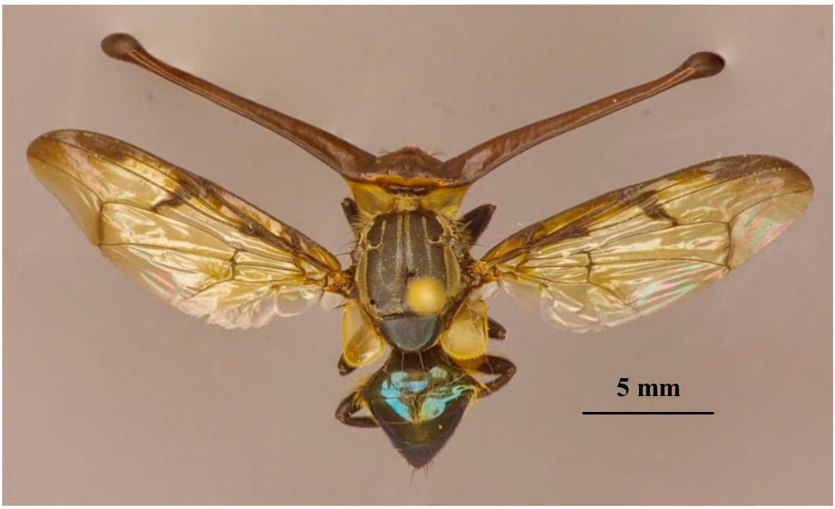


Fig. 1. *Achias tennenti* sp. n., holotype male. Photo by D. Britton.

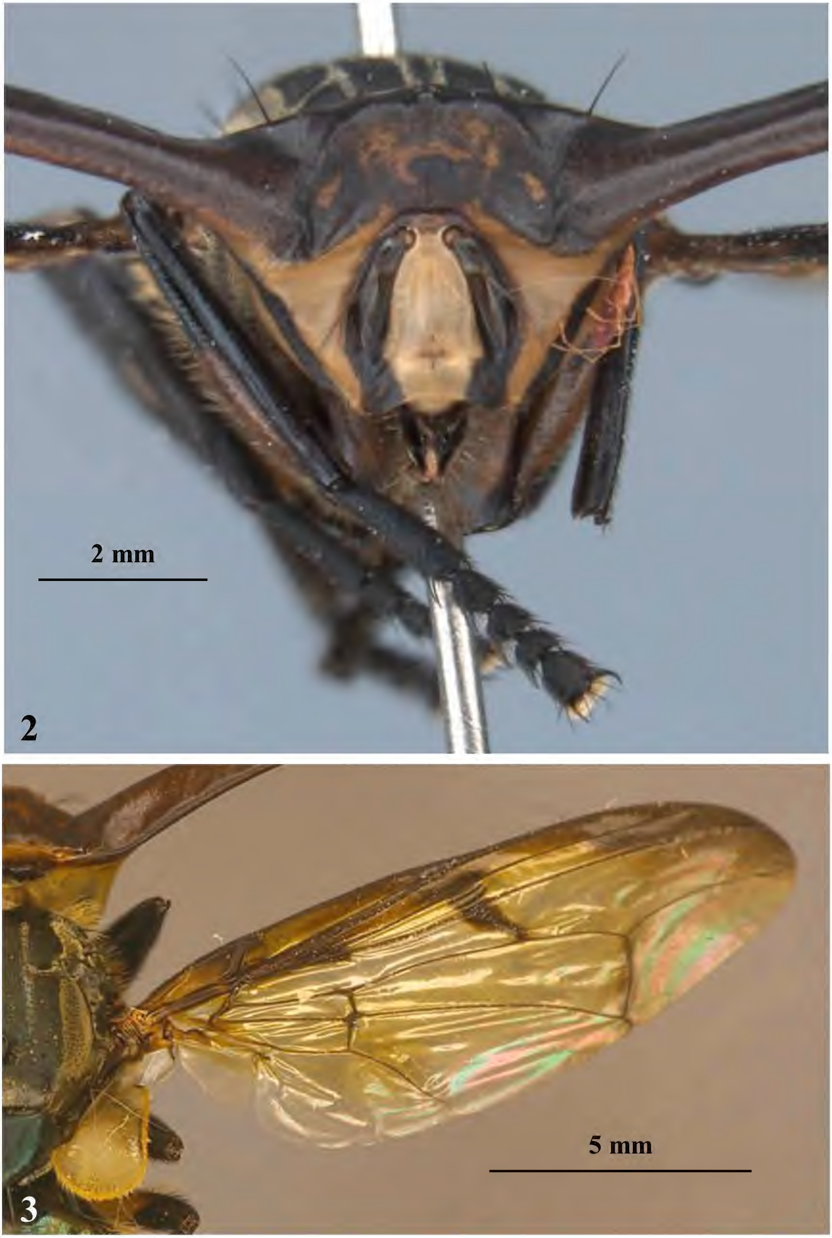
Description. Male (Fig. 1): length of body 11 mm; length of wing 12.5 mm. Head mostly fulvous except most of frons dark to blackish brown, this colour not extending beyond lunule but extending over the eye-stalks, which are darker dorsally than ventrally. Vertical setae present and black. Occiput with a narrow blackish brown stripe behind vertex that broadens medially to reach upper border of neck. Eye-stalks elongate, 10 mm long in holotype, a little shorter in one paratype and about half as long as holotype in second paratype. Lunule blackish brown. Face (Fig. 2) fulvous with a small, indistinct dark marking in centre at level of antennal apices, this mark not forming a distinct medial vitta; a pair of black vittae along antennal furrows from base to epistome. Cheeks fulvous with a black lateral vitta reaching or almost reaching epistome and extending narrowly along ventral base of eye-stalk. Antennae with all segments blackish brown; shorter than face; first flagellomere rounded at apex; arista plumose. Mouthparts blackish brown.

Thorax dorsally blackish with a very weak bluish reflection that is stronger on scutellum. Scutum with narrow, brownish and pale-microtrichose submedial and dorsocentral vittae that unite in posterior portion to form narrow, U-shaped vittae, plus broader lateral vittae that weakly unite along posterior margin; these vittae are separated by a narrow medial and broad submedial and dorsolateral blackish vittae that are weakly microtrichose and appear distinctly rugose; with postpronotal, anterior notopleural, notopleural, anterior supra-alar, posterior supra-alar and prescutellar acrostichal setae present and well developed. Scutellum a little less than twice as wide as long, semicircular, without additional hairs or setulae apart from the 3 pairs of well developed marginal setae; entirely blackish with a bluish reflection. Pleura largely brown without distinct darker spots or patches.

Legs brownish black except basal 3/5 of femora orange, darkest on fore femur where only evident along posterior margin; fore tarsi (Fig, 2) black with basal segment about 5 times as long as broad and about as long as segments 2-5 combined.

Wing (Fig. 3) hyaline with a dull yellow tinge and a complete brown costal band that becomes yellowish brown in basal and costal cells, in submarginal cell below subcostal cell and over most of cell r_{2+3} except where intersected by a dark brown indentation from costa over R-M crossvein and at apex from level of DM-Cu crossvein, where it forms a dark brown apical area from apex of vein R_1 in cell r_1 to apex of vein M; crossvein DM-Cu covered by a narrow brown infuscation of slightly variable width. Squama (Figs 1, 3) buff coloured, dilated and broadly rounded posteriorly, the outer margin straight.

Abdomen shiny with a strong greenish blue reflection; broadly subtriangular with base broad and not petiolate; tergite III with pubescence very short except longer medially; tergite V about twice as long as tergite IV. Aedeagus (Fig. 4) with glans relatively short (0.58 mm) and apical filaments very long (3.27 mm), about 5 times as long as glans in paratype examined.



Figs 2-3. *Achias tennenti* sp. n., holotype male: (2) face and fore tarsi (note mite below base of eye stalk at right); (3) wing and squama. Photos by D. Britton.

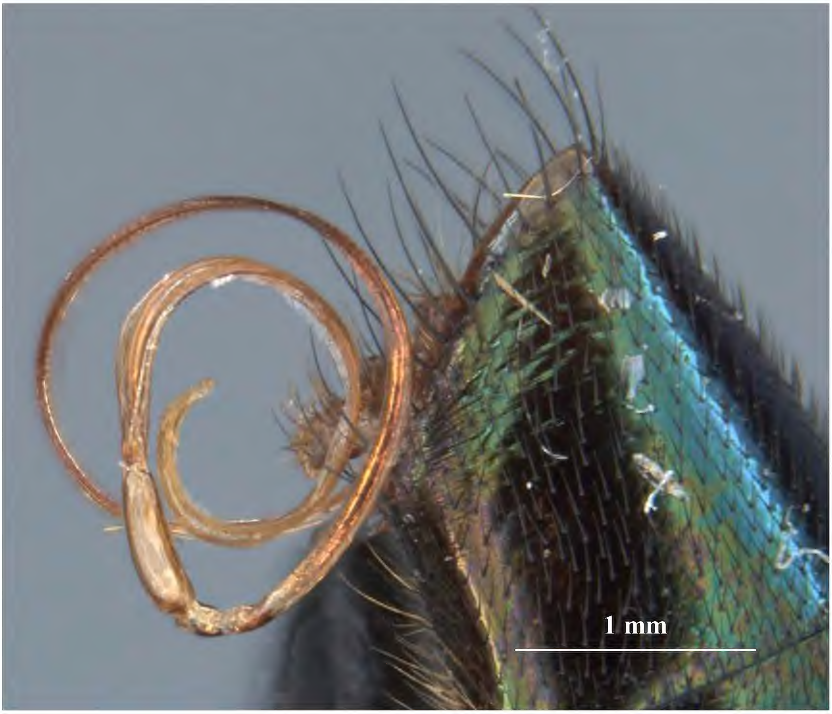


Fig. 4. *Achias tennenti* sp. n., aedeagus of paratype male. Photo by D. Britton.

Distribution. Known only from Fergusson Island, Papua New Guinea.

Etymology. Named after the collector, John Tennent, in recognition of his efforts in obtaining this new species.

Comments. Achias tennenti belongs in Section 2 of McAlpine (1994). It keys to *A. gressitti* McAlpine (couplet 78 in McAlpine 1994) from Papua Province (Indonesia), which, although known only from females, has tawny rather than blackish brown antennae. It most resembles *A. latividens* Walker, differing in the lack of the medial facial vitta, darker antennae, blackish brown rather than tawny tibiae, darker costal band (largely pale yellowish brown in *A. latividens* from Papuan islands), shorter glans (1-1.4 mm in *A. latividens*) and much longer filaments. The wing markings in *A. tennenti* are also very similar to those of the Australian *A. australis* Malloch, which also has dark brown antennae, but in that species the face has a dark medial vitta, the fore femora have distinct black posteroventral spines distally, the squamae are greyish white and the aedeagus has the filaments only 1.1-1.2 x as long as the glans (Malloch 1939, McAlpine 1994). *Achias tennenti* further differs from all the above species in having a narrow dark medial vitta on the scutum.

Discussion

Four species of *Achias* are now known from the D'Entrecasteaux group of islands: *A. attrahens* (Walker) and *A. obliquus* McAlpine from Normanby Island, *A. tennenti* from Fergusson Island and *A. lativídens* from both Normanby and Fergusson Islands, the latter locality recorded by Malloch (1939). Two additional species, *A. longividens* Walker and *A. rothschildi* Austen, are known from mainland areas of Milne Bay Province. These species all belong in McAlpine's (1994) Section 2 except *A. attrahens*, a widespread species referred to Section 1. The other Section 2 species recorded from Milne Bay Province differ from *A. tennenti* in characters noted by McAlpine (1994) and in the following key, including the much shorter filaments on the glans.

The three type specimens of *A. tennenti* were collected on the summit of Mt 'Oitabu at 1804 m, one on a leaf and two at dung, both recorded as similar collection sites for other *Achias* species by McAlpine (1994).

Key to *Achias* species known from Milne Bay Province

Derived largely from McAlpine (1994).

1 Scutellum with numerous pale socket-based hairs on lateral parts and a variable number on apical margin [widespread over mainland New Guinea plus Karkar and Normanby Is] .... *A. attrahens* (Walker)

– Scutellum not haired, or rarely with 1 or 2 hairs on each side aligned with marginal setae 2

2 Wing with a complete, obliquely transverse brown band enclosing both R-M and DM-Cu crossveins; scutum black with microtrichosity [pruinescence] largely restricted to vicinity of transverse and scutellar sutures [known only from Normanby I.] .... *A. obliquus* McAlpine

– Wing without a complete, obliquely transverse brown band enclosing both R-M and DM-Cu crossveins; scutum with microtrichosity [pruinescence] extensive 3

3 Fore tarsus slender, segment 1 *ca* 9-10 times as long as wide in males, a little shorter in females; postpronotal seta absent [eastern Papua New Guinea: Madang, Morobe, Eastern Highlands, Central, Oro and Milne Bay Provinces] .... *A. rothschildi* Austen

– Fore tarsus broader, segment 1 at most 5 times as long as wide; postpronotal seta present 4

4 Face without a medial blackish vitta; tibiae blackish brown to black; aedeagus with filaments about 5 times as long as glans [known only from Fergusson I.] .... *A. tennenti* sp. n.

– Face with a medial blackish vitta; tibiae tawny; aedeagus with filaments about 2 times as long as glans 5

5 Wing with DM-Cu crossvein enclosed in a dark brown patch separate from costal band; head with dark cheek stripe broadly united ventrally (before epistome) with dark vitta through antennal furrow [widespread across southern half of New Guinea, including Aru I.] .... *A. longividens* Walker

– Wing with DM-Cu crossvein not enclosed in a dark brown patch, at most a faint darkening around the vein; head with dark cheek stripe not united ventrally (or at most only narrowly along epistome) with dark vitta through antennal furrow [widespread over New Guinea from Waigeo to the Lousiades, including Aru, Normanby and Fergusson Is] .... *A. lattividens* Walker

Acknowledgements

I thank John Tennent for the opportunity to study this new species and Dave Britton and Sally Cowan (Department of Agriculture and Water Resources, Cairns) for the photographs and logistical support respectively.

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NEW HOST RECORDS OF THE ROVE BEETLE *MYOTYPHLUS NEWTONI* SOLODOVNIKOV & JENKINS SHAW, 2016 (COLEOPTERA: STAPHYLINIDAE: STAPHYLININAE), WITH NOTES ON ITS ASSOCIATION WITH MAMMALS

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Abstract

The rove beetle *Myotyphlus newtoni* Solodovnikov & Jenkins Shaw, 2016 is reported from two new rodent hosts from Victoria, Australia. Based on the preservation of one of the specimens with its mandibles clasping rodent hair, the association of *Myotyphlus* with mammals is discussed.

Introduction

The genus *Myotyphlus* Fauvel, 1883, a member of the Staphylinini subtribe Amblyopinina, includes three species found in Tasmania, Victoria and New South Wales. Two of them were recently described (Solodovnikov and Jenkins Shaw 2017), where available data on the peculiar mammal-associated bionomics of *Myotyphlus* were synthesized. In particular, it was stressed that *Myotyphlus* represents a phylogenetic lineage different from more diverse and specialized amblyopinines from the Neotropical Region. Thus, the association with mammals in *Myotyphlus* arose independently from similar processes in the amblyopinines from the Neotropical Region. In general, behavioural and ecological details of the association between either Neotropical Amblyopinina or *Myotyphlus* and their host mammals are poorly known and mainly restricted to observations of *Amblyopinus* Solsky, 1875. Seevers (1955) observed that the natural mammal hosts do not appear to react to the presence of the *Amblyopinus* beetles on their bodies; however, when the beetles were put on an unnatural host they were quickly groomed out (Ashe and Timm 1987a). *Amblyopinus* species occur in the fur of their hosts nocturnally, whereas diurnally the beetles are active in the host's nest material (Ashe and Timm 1987b).

Prior to this study, *Myotyphlus* had been recorded from five species of mammals across three genera: 3 species of *Rattus* Fischer de Waldheim, 1803, 1 species of *Pseudomys* Gray, 1832 and 1 species of *Antechinus* Macleay, 1841 (Solodovnikov and Jenkins Shaw 2017). Specimens have also been collected from bat guano and a pitfall trap. No species of *Myotyphlus* appears to be host specific or associated with any particular mammalian lifestyle. Earlier records of *M. newtoni* were from *Rattus fuscipes assimilis*

(Gould, 1858), *R. fuscipes greyi* (J.E. Gray, 1841) and from bat guano (Solodovnikov and Jenkins Shaw 2017). Here, we report newly collected specimens of *M. newtoni* from two new host species of *Pseudomys.* We touch upon the biology of *Myotyphlus,* based on new insights from one of those specimens.

Materials and methods

Specimens of *M. newtoni* were studied using a Leica MZ APO dissection microscope. Label data are repeated verbatim with forward slashes '/' indicating the separation of labels. Photos were taken using a Canon EOS 6D attached to a Leica M205C microscope and stacked using Zerene Stacker software.

Results

New records of Myotyphlus

So far, species of *Myotyphlus* can be distinguished from each other only by the shape of the paramere of the male genitalia (Solodovnikov and Jenkins Shaw 2017). The three males studied here were easily identified as *M. newtoni* and the two females collected in association are presumed to be conspecific (see Material examined below).

Myotyphlus newtoni Solodovnikov & Jenkins Shaw, 2016

Material examined. 1 ♂, AUSTRALIA: Victoria, Wilsons Promontory NP, 9.viii.2016, ex. *Pseudomys novaehollandiae* / ID: Z55787, M. Kwak ID: ER24; 2 ♂♂, 2 ♀♀, AUSTRALIA: Victoria, Grampians-Gariwerd NP, 24.vii.2016, ex. *Pseudomys fumeus* / ID: 0481, M. Kwak ID: ER29.

Specimens of *Myotyphlus newtoni* were collected from two new host species: one male from an adult male New Holland Mouse (*Pseudomys novaehollandiae* (Waterhouse, 1843)) (-38.8835ºS, 146.2421ºE) and 2 males and 2 females from an adult male Smoky Mouse (*P. fumeus* Brazenor, 1934) (-37.3174ºS, 142.3292ºE). Both hosts were trapped during the night and examined within three hours of sunrise.

One male collected from *P. fumeus* (Grampians NP, Victoria) is preserved with its mandibles clutching a cluster of mammalian hair, presumably from the host (Figs 1-2).

Discussion

Our study of recently collected specimens of the rove beetle genus *Myotyphlus* resulted in new records of the recently described *M. newtoni*, constituting a range expansion for the species and introducing new mammalian host records. The latter are two vulnerable species of rodent endemic to southeastern Australia – the New Holland Mouse (*Pseudomys novaehollandiae*) and the Smoky Mouse (*P. fumeus*) (Woinarski and Burbridge 2016a, b). The Smoky Mouse (*P. fumeus*) is federally listed as

endangered under the Australian Government Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). One male specimen from *P. fumeus*, preserved with its mandibles clutching several hairs, presumably from the fur of its rodent host, suggests that *M. newtoni* attach themselves to the host by grasping clumps of its fur in their mandibles (Figs 1-2). In addition, all specimens of *M. newtoni* were collected from hosts that were trapped at night. This aligns with previous observations by Ashe and Timm (1987b) for the two species of *Amblyopinus* in the neotropics; however, it remains unknown where *Myotyphlus* species occur diurnally. It seems plausible that *Myotyphlus*, like *Amblyopinus*, occurs in the fur of its hosts to gain access to their nests, where the beetles probably feed on mammalian ectoparasites such as ticks, mites and fleas.

Figs 1-2. Male *Myotyphlus newtoni* Solodovnikov & Jenkins Shaw clasping the fur of *Pseudomys fumeus*: (1) dorsal view; (2) ventral view. Arrows indicate mandibles locked around hair shafts.

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ESTABLISHMENT OF THE EAST AUSTRALIAN MASKED BEE *HYLAEUS NUBILOSUS* (SMITH) (HYMENOPTERA: COLLETIDAE: HYLAEINAE) IN WESTERN AUSTRALIA

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Abstract

Hylaeus (Hylaeorhiza) nubilosus (Smith) is a common, widespread, native bee endemic to the eastern States of Australia. It is recorded from several, mostly suburban, sites in the Perth region of southwestern Western Australia and appears to be well established. The species nests in abandoned mud wasp nests in synathropic situations and might have been transported across Australia by human traffic.

Introduction

Hylaeus (Hylaeorhiza) nubilosus (Smith, 1853) (Figs 1-4) is a common species of masked bee (subfamily Hylaeinae) endemic to eastern Australia (Halcroft and Batley 2014). This species has a broad range, encompassing Victoria all the way up the east coast to Cairns in northern Queensland, as well as occurring in Tasmania (Atlas of Living Australia 2017, Houston 1981). This paper reports recent records from south-west Western Australia.

Hylaeus nubilosus is one of the most common of the hylaeinae bees, most of which nest in pre-made cavities (Almeida 2008, Halcroft and Batley 2014, Houston 2011), such as those created by wood-boring beetles, or in hollow pithy stems and will readily occupy ‘bee hotels’ made out of wooden blocks with holes drilled in them or bundles of bamboo of appropriate diameter (Halcroft and Batley 2014, Fortel *et al*. 2016). However, *H. nubilosus* prefers to nest in abandoned nests of mud-dauber wasps (Sphecidae) and potter wasps (Vespidae: Eumeninae) (T.F. Houston pers. comm.).

Hylaeus nubilosus, the sole species in subgenus *Hylaeorhiza* Michener, 1965 (Houston 1981), is a medium-sized (6-9 mm) masked bee with a conspicuous yellow thoracic ‘badge’ in the middle of the scutellum and metanotum (Fig. 1). Other diagnostic features include the mesosternum with a prominent transverse ridge anterior to each mid coxa, the propodeum almost wholly vertical with a steeply sloping dorsal surface that is smooth and rounding onto the posterior surface and, unlike other genera and subgenera, the lack of outer apical spines on the hind tibia (Houston 1981). The body of both sexes is black, with a yellow spot in front of the wings on the mesosoma (Figs 2-4). Like many Hylaeinae, the sexes are dimorphic, the female having cream markings on the lateral margins of the paraocular area as well as a medial cream stripe on the clypeus (Fig. 2), whereas in the male the cream facial markings encompass the entire paraocular area and clypeus. Males also have some yellow on the scape of the antennae. As with all hylaeines, females lack scopae and, rather than having specialised pollen-carrying hairs, ingest pollen and carry it in the crop – a derived condition (Plant and Paulus 2016).

Figs 1-4. *Hylaeus (Hylaeorhiza) nubilosus* females: (1-3) from Wilson, Western Australia: (1) dorsal view; (2) anterior view; (3) lateral view. (4) collected dead, Wembley, Western Australia.

Observations

The first record of this species in Western Australia occurred in 2002. R.P. McMillan, a research associate of the WA Museum, donated a mud nest collected in the Perth suburb of Bassendean from *Sceliphron formosum* (Smith, 1856) (Sphecidae) to the WA Museum, from which five specimens of *H. nubilosus* emerged: four males on March 15 followed by a single female some weeks later on April 29. The specimens were held in the Museum's entomology collection along with the remains of the host nest but were not lodged or given accession numbers.

The first publicly documented record was of a female photographed on 2 January 2015 in Jandakot, an outer southern suburb of Perth and uploaded to the citizen science website 'Bowerbird' in May 2016 (Walker 2016). It was nesting in an old potter wasp nest in a hole in the mortar of house bricks and was entered as the first WA record in the Atlas of Living Australia (Atlas of Living Australia 2017). Another record was posted on 'Bowerbird' on 7 September 2016, of a sighting in May 2015 showing a female at a longicorn beetle gallery in dead wood, located in North Greenbushes.

On 24 March 2016, a dead female in poor condition (Fig. 4) was taken by the author on an inner window sill of a house at Wembley, an inner northern Perth suburb. It is likely that the bee was searching for a mud-dauber or potter wasp nest as these synanthropic species often build in crevices or under eaves of residential houses (pers. obs.).

The next report was recorded on my citizen science Facebook group (Prendergast 2017), created as part of my PhD project 'Determinants of native bee assemblages in urban habitat fragments in the southwest Australian biodiversity hotspot and interactions between honeybees (*Apis mellifera*) and native plant-pollinator communities'. A member of the group, Mrs K. Stuart, recorded an observation of *H. nubilosus* on 18 January 2016 at Creyk Park, a small park incorporating revegetated native flora in Armadale, on the south-west outskirts of Perth. The species identification was confirmed as a high-quality photograph was also uploaded (Fig. 5). The specimen was a female foraging on the closed inflorescences of *Corymbia ficifolia* (Myrtaceae). Upon enquiring about this species to ask permission to use the image, more photos of *H. nubilosus* were obtained, taken on the 23 November 2016. The female was photographed tending its nest in old mud-dauber *Sceliphron formosum* mud-cell nests situated under the eaves on the front porch of the photographer's house in Armadale (Figs 6-7).

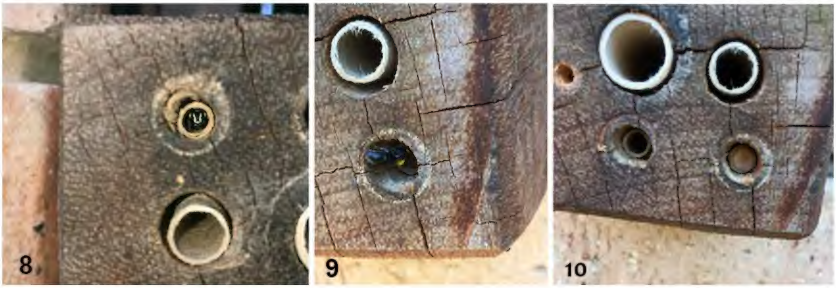
Further inquiries revealed that *H. nubilosus* had been collected during faunal surveys conducted by David Knowles (a biological survey consultant): a female at Gwambygine Pool Conservation Reserve in 2010, a female in a suspended blue passive-lure bucket in banksia woodland at Ioppolo Road, Chittering on 8 October 2011, another female at Mt Helena on 16 March 2013, trapped in an Orchid nursery shade-cloth corner and, most recently, a female recorded during the Bullsbrook Nature Reserve Macroinvertebrate and Herpetofauna Inventory Survey, also photographed at this locality in January 2013 by Fred and Jean Hort.

Specimens of both sexes, identified by Dr Terry Houston, were also obtained during surveys conducted by Dr Mark Murphy (pers. comm.) as part of his thesis on Hymenoptera in the wheatbelt region of WA. The specimens were reared from cardboard bee tubes collected from jarrah trap-nests installed in Nov-Feb 2012/13 and Nov-Apr 2013/14 in Wandoo woodland sites on farmland across the south-west Wheatbelt (from Brookton in the north to Katanning in the south). One-hundred and six nests tentatively assigned as belonging to *H. nubilosus* were collected from 13 of the 48 sites surveyed but there is uncertainty regarding this designation as the majority of nests failed to have adults emerge; hence assignment to *H. nubilosus* was unconfirmed, given that nests of *H. nubilosus* are very similar to another hylaeine species collected, *Hylaeus (Euprosopis) honestus* (Smith, 1879). Nests were 3 mm, 5 mm and 7 mm in diameter, with a strong preference for 5 mm holes; 31 adults were successfully reared (M. Murphy pers. comm.).

Figs 5-7. *Hylaeus (Hylaeorhiza) nubilosus* females: (5) foraging on incompletely open buds of *Corymbia ficifolia*; (6-7) nesting in abandoned mud-dauber nests (Photos by K. Stuart).

The most recent records were taken by the author while surveying a residential garden in the inner SW Perth suburb of Wilson. On 5 December 2016, a female (Figs 1-3, now in the Western Australian Museum: E 97780) was netted at around midday while hovering at the side of a brick house and presumably looking for a place to nest. Numerous mud-dauber wasp nests were present on the walls of the property but none was observed to be in use by *H. nubilosus*. As with all of my sites, eight bee hotels were installed under eaves or in trees around the site, consisting of a 10x10x20 cm jarrah block with fifteen 12 cm deep holes drilled into it, in which cardboard tubes of 4 mm, 7 mm and 10 mm diameter (5 per diameter) were inserted.

This site was revisited on 30 October 2017 and, in one of the bee blocks located on a window sill, two females were observed nesting in 4 mm bee tubes (Fig. 8). These were the only nests that were occupied on the property by *H. nubilosus* during this survey. One female was working on the nest cap and completed the nest during the survey (Figs 9-10). She then investigated an old mud-dauber nest on the mortar between the bricks adjacent to the window sill and was captured for reference purposes.



Figs 8-10. *Hylaeus (Hylaeorhiza) nubilosus* females nesting in bee block: (8) in 4 mm bee tube; (9) constructing the nest cap; (10) completed nest.

Discussion

Given its predilection for nesting in abandoned nests of mud-dauber wasps, which in turn often nest in anthropogenic building materials, it is likely that this is the mode by which *Hylaeus (Hylaeorhiza) nubilosus* entered Western Australia, presumably with human assistance. *H. nubilosus* has been recorded nesting in abandoned mud-nests of a diversity of wasps from the families Trypoxylidae, Sphecidae and Eumenidae, in diverse localities including brick walls, roots and tunnels in soil at bases of fallen trees and inside hollow trees and logs (Houston 1969).

Based on its wide distribution, *H. nubilosus* can be considered to be a highly adaptable bee, able to tolerate a range of habitats. It has been recorded in eastern Australia in both natural forests (Hingston 1999) and urban areas, where it will occupy bee hotels, mud walls of adobe houses and nail holes (Makinson *et al*. 2016, Rayment 1935). It is polylectic and has been recorded foraging on both native and non-native flora (Houston 1981), which also aids in its ability to colonise urban habitats (Makinson *et al.* 2016) and would contribute to its wide geographic range and more recent establishment in Western Australia. Presently, out of the 1062 current records for *H. nubilosus* on the Atlas of Living Australia website (as of 7 June 2017), there are now six reports from WA (one of which is based on a misidentification – T.F. Houston pers. comm.), suggesting that this species is now well established.

However, the black and yellow markings and relatively hairless bodies of these bees mean they might often be mistaken for wasps. Hence, although *H. nubilosus* might already be widely distributed and increasing in numbers

throughout southwestern Western Australia, many observers might fail to recognise this species, let alone recognise it as a bee. It is hoped that this paper will facilitate recognition and enable the distribution of *H. nubilosus* to be more accurately mapped.

Acknowledgements

The author would like to express her appreciation to Dr Terry Houston for his taxonomic expertise, the Western Australian Museum for allowing her to use their camera to take the photographs for Figs 1-3, Mrs K. Stuart for her valuable contribution to ‘Bees in the ’burbs’ and for supplying her photographs, Dr Mark Murphy for his Wheatbelt records and Mark Donald for his encouragement.

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CORRECTIONS TO A PAPER REGARDING IDENTIFICATION AND HOST PLANT OF *ERIONOTA THRAX* LINNAEUS (LEPIDOPTERA: HESPERIIDAE) IN PAPUA NEW GUINEA

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Abstract

Erionota thrax Linnaeus, 1767 populations reported from West New Britain, Papua New Guinea by the present authors in 2011, erroneously attributed to *E. t. hasdrubal* Fruhstorfer, 1910, are shown to belong to *E. t. thrax*. The record of oil palm (*Elaeis guineensis*) as a host plant for this species was also in error and should be disregarded; the correct host plant is confirmed as cultivated banana (*Musa* sp.).

Introduction

Dewhurst and Tennent (2011) reported three butterfly species, including *Erionota thrax hasdrubal* Fruhstorfer, 1910, feeding on oil palm, *Elaeis guineensis*, on the island of New Britain, Bismarck Archipelago, Papua New Guinea. These data were based on observations and rearing by CFD.

Discussion

In a comprehensive review of *Erionota* Mabille species and their status as pests of plant species, Cock (2015) claimed – rightly – that the *Erionota* specimen we illustrated was not, as we had assumed, *E. thrax hasdrubal* and offered the suggestion that it represented either *E. t. thrax* Linnaeus, 1767, *E. torus* Evans, 1941, an aberrant individual of *E. acroleuca* Wood-Mason & De Nicéville, 1881 (lacking the pale forewing apex of that species), or 'some other taxon of *Erionota*'. Cock (2015) acknowledged that, of the suggested taxa, only *E. t. thrax* was known from New Britain; the not unreasonable suggestion that the possible correct species identification included *E. acroleuca* was based on the fact that *acroleuca* is known to feed on palms and that neither *E. thrax* nor *E. torus*, both well documented pests of banana (*Musa* spp), has previously been reported feeding on palms. Cock (2015) did not indicate how *E. t. hasdrubal* differed from *E. t. thrax*.

Further, Cock pointed out – once again correctly – that Parsons (1998) had wrongly presented Papua New Guinea reports of *Erionota* as *E. thrax hasdrubal*, but in this case suggested (Cock 2015: 6) that Parsons' text and illustrations (Parsons 1998: 160, pl. 4) both represented *E. t. thrax*, 'based on the characters in Evans [1941; 1949]'. Illustrations by Parsons (1998) and Dewhurst and Tennent (2011) clearly represent the same taxon. Since Cock (2015) did not offer features by which to separate *E. t. thrax* and *E. t. hasdrubal* and the species was said not to occur on palms, three questions arise: (1) what differences, if any, separate these two *E. thrax* taxa; (2) what is the correct identification of the records of *E. t. hasdrubal* presented by Parsons (1998) and Dewhurst and Tennent (2011); (3) does *E. thrax* utilise

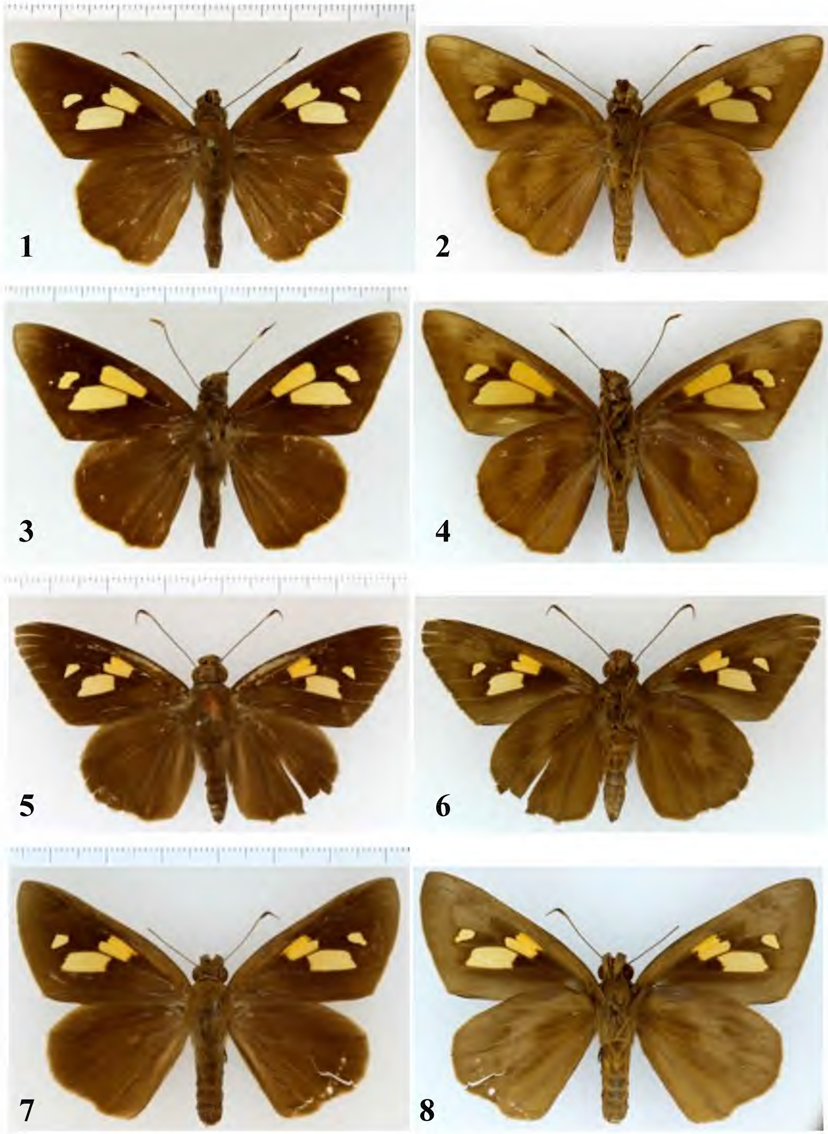
oil palm (*Elaeis guineensis*) as well as banana (*Musa* spp). The primary purpose of the present paper is to correct, and to accept responsibility for, two fundamental errors in our publication.

The first question seems to have been largely overlooked in the literature. Fruhstorfer's description of *E. t. hasdrubal* (Fruhstorfer, 1910: 102) was brief, but accurate: '… differiert von den genannten Rassen dadurch, das der gelbe Glasfleck der Vdfglzelle ebenso land oder fast ebenso land ist als der darunter lagernde Medianfleck. Distal ist diese ungewöhnlich ausgedehnte Zellmakel auch nicht eingekerbt wie bei thrax von andern Fundorten …'. [loose translation: differs … by the fact that the yellow hyaline spot of the forewing cell is just as long or almost as long as the median spot beneath it. Distally, this unusually broad cell spot is also not notched as with *thrax* from elsewhere]. Evans (1941, 1949) is potentially confusing, but he does record *E. t. hasdrubal* as having the 'forewing cell spot 9 mm. long in ♂, outwardly rounded'.

The type locality (TL) of *E. t. thrax* (Figs 1-2) is Java; that of *E. t. hasdrubal* (Figs 3-4) is Bacan, two thousand kilometres to the northeast, in the northern Moluccas. Parsons (1998) gave a detailed account of the few specimens that he believed to be *E. t. hasdrubal* then recorded from Papua New Guinea, but made no comparison with *E. t. thrax*. The latter occurs from Burma and Indo China, through Sundaland and the Philippines, to Borneo and Sulawesi; the former was previously known from several of the North Maluku islands (Halmahera, Bacan, Ternate, Obi). Parsons (1998) made the perfectly understandable and geographically plausible assumption that the *E. t. thrax* populations present in Papua New Guinea had probably spread from the nearest source: *E. t. hasdrubal* in the Moluccas. With *ca* 1,000 butterfly species to deal with in his monumental tome, he can perhaps be forgiven. The present authors (Dewhurst and Tennent, 2011) followed Parsons (1998) in wrongly assuming that the *E. t. thrax* found on New Britain was also *E. t. hasdrubal*; we accept responsibility for our own error in identification.

In order to avoid future confusion and in view of a lack of any modern illustrations of *E. t. hasdrubal*, a male from its type locality, together with *E. t. thrax* from Sulawesi and both sexes of *E. t. thrax* from West New Britain, Papua New Guinea, are illustrated here (Figs 1-8). Note that as Fruhstorfer (1910) declared, the yellow streak in the forewing cell is significantly longer in *E. t. hasdrubal* than in *E. t. thrax* and that the distal extremity of the streak is 'blunt', almost flattened, unlike the sharply 'notched' ('eingekerbt', to use Fruhstorfer's word) of the latter.

In the process of resolving these issues, a pair of the *Erionota* in question (Figs 5-8), including the female mentioned and illustrated in our original paper (Dewhurst and Tennent 2011, fig. 1), were obtained on loan from the Papua New Guinea Oil Palm Research Association (PNGOPRA) collection at Kimbe, West New Britain.



Figs 1-8. *Erionota thrax*: (1-2) *E. t. thrax* (Sulawesi), ex-J Waterstradt, 1904 (BMNH): (1) male upperside; (2) male underside. (3-4) *E. t. hasdrubal* (Bacan), W. Doherty, August 1887 (BMNH): (3) male upperside; (4) male underside. (5-8) *E. t. thrax* (West New Britain), reared on banana (PNGOPRA): (5) male upperside; (6) male underside; (7) female upperside; (8) female underside.

Neither had been seen by WJT previously; however both were labelled as having been reared on banana, not oil palm. CFD accepts full responsibility for this error. The female *Erionota* illustrated by the authors in 2011 is *E. t. thrax*. *Erionota acroleuca* was suggested as a possibility by Cock (2015), based on its known preference for palm as a host plant, but it was an unlikely candidate, since it has a distinctive pale forewing apex in males, quite unlike either *E. thrax* or *E. torus*. A key for separating *Erionota* taxa found in the Philippines (De Jong and Treadaway 2007) presents the couplet: 'apex of forewing rounded and termen convex = *torus* / apex of forewing acute and termen straight = *thrax*'. This, combined with genitalia drawings on the same page and illustrations of adults (De Jong and Treadaway 2008), provides an accurate means of separation. The pair of *E. t. thrax* in Figs 5-8 has been returned to the PNGOPRA collection.

In summary, it is acknowledged that references and illustrations provided by both Parsons (1998) and Dewhurst and Tennent (2011) refer to *E. t. thrax*, not *E. t. hasdrubal* as previously claimed. Further, since we know of no reliable source that *E. thrax* utilises oil palm as a host plant, our claim to the contrary in Dewhurst and Tennent (2011) must be disregarded.

Acknowledgements

CFD is grateful to Matthew Cock for bringing this to his attention and to PNGOPRA for loaning specimens that enabled us to resolve this issue.

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ARGYNNIS HYPERBIUS INCONSTANS BUTLER, 1873 (LEPIDOPTERA: NYMPHALIDAE: HELICONIINAE): A REVIEW OF ITS COLLECTION HISTORY AND BIOLOGY

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Abstract

The Australian Fritillary, *Argynnis hyperbius inconstans* Butler, 1873, is an endemic taxon known only from Gympie, Queensland to just north of Port Macquarie, New South Wales. It is regarded as the 'rarest' Australian butterfly and is nationally listed as Critically Endangered. In this study, specimen collection data, field observations and published literature are reviewed. The species has always been rarely observed; hence, prior to 1976 when a prolific fritillary site was discovered at Woondum, just south of Gympie, fewer than 100 specimens with label data were known. The last specimens recorded from Queensland were collected just west of Coolum Beach in 1988 and the last specimen collected in New South Wales was in 2001, from near Limeburners Creek National Park, approximately 5 km north of Port Macquarie. There are currently no known extant populations of *A. h. inconstans*. Its main recorded habitat is localised damp or wetland zones that have experienced a specific degree of ideal anthropogenic disturbance, where its primary host plant *Viola betonicifolia* (Violaceae) grows in high densities. Evidence suggests that *V. banksii* might also be a natural host plant. The butterfly's ecology and occasional proliferation seem linked to proliferation of its primary host plant within these moist disturbed areas. Once these ideal conditions no longer exist, butterfly populations appear to decline and disappear. This same ecological relationship with specific anthropogenically disturbed areas with high densities of violets is also believed to assist in the maintenance of populations of other *A. hyperbius* (L.) taxa in India, Sri Lanka, Vietnam, Japan and Hong Kong. Thus, it appears that the occasional proliferation of *A. h. inconstans* might relate to conditions allowing proliferation of its host plant together with a chance vagrant initiating the population. Recent searches in areas where the butterfly once occurred have been unsuccessful but its ability to seek out suitable wet zones could be exploited to discover areas where it might still exist, particularly near Woondum in Qld and near Limeburners Creek National Park in NSW. These areas are where the butterfly has been known previously and where undisturbed forest types, including lowland wetlands, still exist nearby. A possible strategy is proposed to create areas of high violet density at these two sites to attract females of *A. h. inconstans* such that its possible presence might be confirmed. Overall, what has exacerbated the butterfly's critical status has been a poor understanding of its ecology and that of its host plants, plus a general confusion by many butterfly workers on how vulnerable and endangered it is.

Introduction

Argynnis hyperbius inconstans Butler 1873, the Australian Fritillary or Laced Fritillary, is endemic to eastern Australia, where it is known only from within the coastal area from Gympie in Queensland to just north of Port Macquarie in New South Wales (Braby 2000). It has recently been listed nationally as Critically Endangered (Department of the Environment and Energy: Australian Government 2017). Adult butterflies frequent damp and swampy habitats (Waterhouse 1932) and the larvae are known to feed on the arrow-leafed native violet, *Viola betonicifolia* Sm. (Violaceae) (Figs 1-3) (Waterhouse 1932, Lambkin and Lambkin 1977), with evidence reported here that *V. banksii* K.R. Thiele & Prober (syn. *V. hederacea* L.G. Adams) (Australian Native Plants: plant name changes 2015) (Figs 4-5) might also be a natural hostplant (Johnston and Johnston 1984, A.F. Atkins pers. comm.).

Figs 1-3. *Viola betonicifolia*: (34) mature plant growing under bamboo thickets close to the historic fritillary site just west of Coolum Beach (2015); (35) flower, pale lilac and white colour morph growing in the Woondum gully (2009); flower, dark lilac colour morph in cultivation, New South Wales.

Figs 4-5. *Viola banksii*: (4) mature plant and (5) flower in cultivation: Dorrigo, New South Wales.

The cosmopolitan tribe of medium to large-sized butterflies known as fritillaries (Simonsen 2006, Tuzov 2003) (Argynnini Duponchel, [1835], Heliconiinae Swainson, 1827) have a characteristic checked pattern of black and tawny-orange spots on the upperside of the wings and an intricate arrangements of silver spots or silver bands on the hindwing undersides (Guppy and Shepard 2001, Tuzov 2003, Tolman and Lewington 2008). The group is roughly divided into the New World or Greater fritillaries, *Speyeria* Scudder, 1872, which exclusively occur in the Nearctic zone of the Americas (Guppy and Shepard 2001, Opler 1998, 1999), and the Old-World fritillaries, now *Argynnis* Fabricius, 1807 (Simonsen 2006), which are primarily confined to the Palaearctic region (Kudrna 2002, Tuzov 2003, Tolman and Lewington 2008, Tshikolovets 2011). Thus, the work of Simonsen (2006) in reinstating *hyperbius* (Linnaeus, 1763) into *Argynnis* has been adopted here.

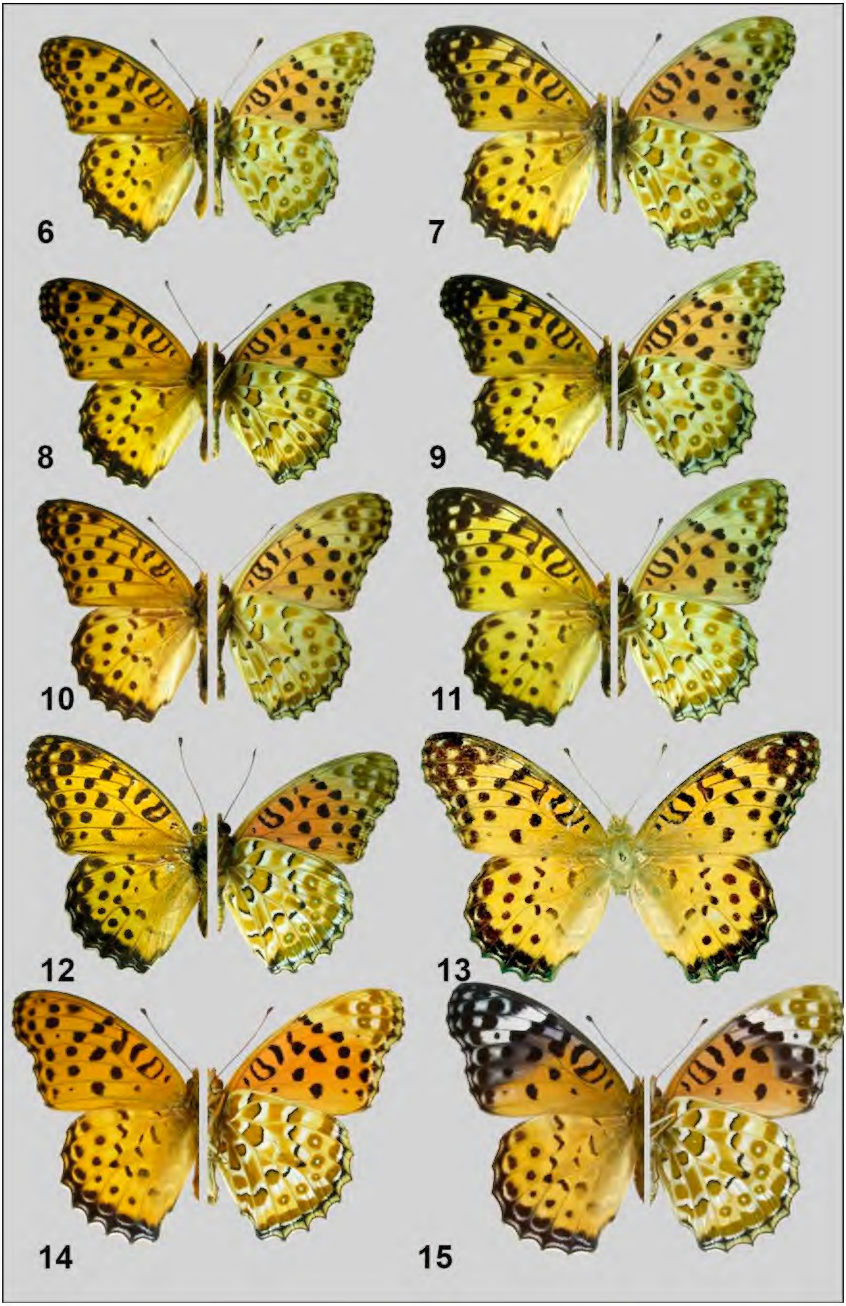
Due to the rarity of *A. h. inconstans* and to correct its current degree of data deficiency, I document here a literature review of the butterfly and a complete chronology of its collection. I also discuss its biology, distribution and some aspects of its ecology and relative abundance. In addition, mostly both sexes of *A. h. inconstans* are illustrated (Figs 6-13) from each of five localities (in Queensland: [1] Woondum; [2] just east of Caboolture, near Ningi; [3] just west of Coolum Beach; and in New South Wales: [4] approximately 5 km north of Port Macquarie; [5] Bora Ridge, near Coraki).

During the preparation of this work, investigations indicated that the taxonomic status of the Australian taxon (species or subspecies) required further investigation, which will be addressed in a future study.

Methods

Label specimen data for *A. h. inconstans* in all Australian State and Federal institutional insect collections, as well as the Natural History Museum, London and accessible private Australian collections, including the database used by Dunn and Dunn (1991), were assembled for this review. Where specimens from some collections could not be personally examined, personal communications were used to gather collection data.

Figs 6-15. *Argynnis hyperbius* subspp. All figures not to scale: upperside left, underside right [forewing lengths, in mm, in square brackets]; Figs 6, 8, 10, 12, 14 (♂♂); Figs 7, 9, 11, 13, 15 (♀♀). (6-13) *A. h. inconstans*: AUSTRALIA: (6-7) E of Caboolture, Qld: (6) 30.x.1987 [33 mm], (7) 8.xi.1987 [35] RG (GRFC); (8-9) W of Coolum Beach, Qld, ex captive ♀ collected 17.iii.1985: (8) emerged 18.v.1985 [32], (9) emerged 1.v.1985 [33], TAL (TLIKC); (10-11) Woondum, 6.25 km S of Gympie, Qld, larva collected 9.i.1977: (10) emerged 25.i.1977 [33], (11) emerged 24.i.1977 [36], TAL (TLIKC); (12) 5 km N. of Port Macquarie, NSW, 17.iv.2001, JM (JMC) [30]; (13) Bora Ridge, near Coraki, NSW, 17.iv.1960, BP (AMSC) [35]. (14-15) *A. h. niugini*: PAPUA NEW GUINEA: Nondugl (Central Highlands), 5500 ft: (14) 4.x.1950 [41], (15) 16.x.1950 [43], WB (ANIC).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The sex of some specimens could not be obtained and these have been noted below. While every attempt was made to assemble all the available collection data, omissions are inevitable but it is hoped that these are few. Only specimens with label data that included a locality or State of capture and a date, indicating at least the year of capture, were included. Observation-only records were not considered for the review, while specimens bred from captive females were also excluded, since they did not indicate field incidence.

Literature on *A. h. inconstans* was reviewed, including published books, peer reviewed and non-peer reviewed papers and reports. In addition, the review included references to the butterfly in several old overseas sources. Literature on the biology and distribution of *A. hyperbius* overseas was also reviewed.

Abbreviations

The following abbreviations refer to public institutions and private collections cited in the text: AFAC – A. Atkins collection, Eudlo, Qld; ABRC – A.B. Rose collection, location possibly Sydney; AM – Australian Museum, Sydney; AMSC – A.M. Sundholm collection, Turrella, NSW; ANIC – Australian National Insect Collection, Canberra; ASMC – A.S. Moore collection, Port Macquarie; CGMC – C.G. Miller collection, Lennox Head, NSW; CW – C. Wyatt theft collection; DBC – D. Bell collection, Brisbane; DoBC – D. Binns collection, Sydney; GAWC – G.A. Waterhouse collection (in AM); GRFC – G.R. Forbes collection, Brisbane; GSC – G. Stibbard collection, Bagotville, NSW; JAKC – J.A. Kershaw collection (in MV); JMC – J. Moss collection, Brisbane; KJBC – K.J. Beattie collection, Brisbane; LMC – L. Matthews collection, Ballina, NSW; MCZ – Museum of Comparative Zoology, Harvard University, Cambridge, MA, USA; MTQ – Museum of Tropical Queensland, Townsville; MV – Museum of Victoria, Melbourne; NHM – Natural History Museum, London; OBLC – O.B. Lower collection (in SAM); QDAFC – Queensland Department of Agriculture and Fisheries collection, Brisbane; QM – Queensland Museum, Brisbane; RGEC – R.G. Eastwood collection (in MCZ); RPMC – R.P. Mayo collection, Pomona, Qld; SAM – South Australian Museum, Adelaide; SGC – S. Ginn collection, Sydney; SJJC – S.J. Johnson collection (in MTQ); SLNSW – State Library NSW, Sydney; SSBC – S.S. Brown collection, Bowral, NSW; TLIKC – joint collection of T.A. Lambkin & A.I. Knight, Brisbane; TPLC – T.P. Lucas collection (in SAM); WAM – Western Australian Museum, Perth.

Results

Collection history

The description of *A. h. inconstans* is based on three type specimens in NHM: 1 ♂ labelled 'Moreton Bay' and 1 ♂, 1 ♀ labelled 'Australia' (Butler 1873). Edwards *et al.* (2001) considered the 'Moreton Bay' specimen to be the holotype. It was possibly collected by Silvester Diggles, who resided in

Brisbane from 1854 until 1880 and sent many Lepidoptera and Coleoptera specimens to Francis Walker at the NHM (Marks 1963). Males of *A. h. inconstans* and other *A. hyperbius* subspecies are superficially similar (*cf.* Figs 12 and 14). Butler (1873), in his description, indicated that the female of *A. h. inconstans* (*e.g.* Fig. 13) differed from other *A. hyperbius* taxa in not having the white subapical band on the upperside of the forewing, a feature typical of *A. hyperbius* (Fig. 15). Butler (1873) provided no information on the etymology of the name *inconstans* but it might have stemmed from the fact that the known female of *A. inconstans* was not consistent with the females of *A. hyperbius* (then known as *A. niphe* Linnaeus, 1767) from Java (Latin *inconstãns* meaning 'inconsistent or changeable': Latdict 2017).

Fourteen specimens of *A. h. inconstans*, presumably *ca* 1900 or earlier but without label data, are in Australian museum collections: 2 ♂♂, 1 ♀ (AM); 1 ♂, 2 sexes unknown (ANIC); 1 sex unknown (MV); 2 ♂♂, 2 ♀♀ (QM); 1 ♂ (SAM) and 1 ♂, 1 ♀ in the Macquarie Collectors' Chest (see Appendix I). In addition, there are 40 other specimens, also presumably *ca* 1900 or earlier, with label data but without dates (Table 1). Two specimens in the database compiled by Dunn and Dunn (1991), collected at Burleigh Heads and Dayboro, Qld, by the late Jean Harslett of Amiens, Qld, no longer exist; her collection, bequeathed to QM, suffered extensive damage by museum beetles and these specimens were presumed destroyed (S. Wright pers. comm.).

Excluding the above, the three types in the NHM and seven specimens in MCZ (ex RGEC), the bulk of the known *A. h. inconstans* specimens are likely housed in Australian collections, although the existence of others in overseas collections cannot be discounted. For example, in the Royal Society of Tasmania's library copy of Kirby (1877), there are marginal notations made by F. Moore indicating that, prior to 1873 when Butler described *A. inconstans*, Moore was aware of another Australian specimen in the 'collection of Coles' at Buckhurst Hill in Essex, England. In Appendix I, additional specimens with locality and date label data that are held in primarily Australian collections are discussed and tabulated in chronological order.

Collection data for *A. h. inconstans* show that it flies in all months of the year and therefore suspended development based on temperature, through larval or pupal diapause, is unlikely. Rearing data since 1976 (TAL unpublished data), showing emergence of adults in every month, support this assumption. This accords with its northern relatives, where no thermal-induced diapause or suspended development has been recorded (Ito 2000), although a drought-induced diapause in *A. h. inconstans* cannot be ruled out (Sands and New 2008).

Specimen data show that the butterfly is almost exclusively recorded from coastal areas between Gympie, Queensland and just north of Port Macquarie, New South Wales, except for the specimen in the SAM (ex. OBLC) allegedly

Table 1. Summary of label data that do not have year of collection for specimens of *Argynnis hyperbius inconstans*; abbreviations of specimen depositories are outlined in the Abbreviations section above; abbreviations for collectors' names are indicated below (*).

Year of collection	Locality	No of specimens	Collector	Specimen depository
-	Ballina, NSW	1♂	GAW	MV
-	Blackall Range, Qld	1♀	FW	QDAFC
-	Brisbane Qld	2♀♀, 1 – sex?	TPL, PKC or AKC, CWW theft	MV, SAM
-	Bulimba, Qld	1♂	RI	SAM
-	Cairns, Qld	1♂	Ex OBLC	SAM
-	Dorrigo, NSW	1 – sex?	IA	ABRC
-	Eumundi, Qld	1♂, 1♀		ANIC
-	Gympie, Qld	3♂♂		AM, ANIC, QM
-	Moreton Bay, Qld	1 – sex?		MV
-	New South Wales	4♂♂, 3 – sexes?	RM, 1♂ *A. niphe*, O, M	MV, QM, ANIC
-	Queensland	2♂♂, 2♀♀	FHB, Mckie	AM, ANIC
-	Richmond River, NSW	1♂, 2 – sexes?	JAK, CWW theft	MV, SAM
-	South Queensland	9♂♂, 3♀♀	TPL, CWW theft, ex TPLC	AM, SAM

* CWW theft – C.W. Wyatt theft, FHB – F.H. Brown, FW – F. Whitteton, GAW – G.A. Waterhouse, IA – I. Archibald, JAK – J.A. Kershaw, Mckie – ?, PKC or AKC – ?, RI – Rowland Illidge, RM – ?, TPL – T.P. Lucas.

from the Cairns district of northern Queensland (Olliff 1888): the veracity of this record is addressed in Appendix I and the locality is not accepted in this study. Apart from four specimens (in ANIC and ABRC) labelled 'Dorrigo', NSW (*ca* 750 m), plus two specimens (in QM and QDAFC) labelled 'Blackall Range', SW of Nambour, Qld (*ca* 450 m), all records are from wet or swampy locations at low elevations. This is in accord with the literature reviewed in Appendix II.

The collecting frequency of *A. h. inconstans* indicates a temporally patchy distribution, with relatively few specimens collected between 1901 and the mid-1970s. From the 19th and early 20th Centuries (roughly prior to 1901), there are 12 known specimens with adequate collection label data (*i.e.* location and at least year of capture), plus the three types in the NHM and the two in the SLNSW. This is a total of 17 specimens known prior to around 1901. From 1901 to 1951 there are 11 known specimens and from 1951 up to and including 1975, just prior to when a prolific site for *A. h. inconstans* was discovered at Woondum, just south of Gympie, another 20 were collected. Therefore, excluding any overseas or local specimens unknown to the author, from the time of European settlement up to and including 1975 there are 48 specimens with adequate collection label data (plus another 54 with little or no label data) housed in public museums and private collections in Australia and in the NHM in London.

Between January 1976 and November 1977, 79 ♂♂ and 34 ♀♀ were collected, predominately as adults but with some as immatures (and almost certainly with more collected and many more reared from captive females), in a horse paddock (Fig. 16) at Keefton Road, Woondum, 6.25 km south of Gympie CBD (-26.237ºS, 152.701ºE) (Binns 1976). Most of the paddock was cleared and contained many spear thistles (*Cirsium vulgare* (Savi) Ten.: Asteraceae) and a gully within the paddock had extensive areas of *Lomandra longifolia* Labill. (Asparagaceae) and *Viola betonicifolia* growing among shallow pools of water and muddy patches (Lambkin and Lambkin 1977). Despite the large number of butterflies collected from this very localised site, the population appeared to have suffered little from this intensive collecting until the site was apparently levelled and drained by a bulldozer sometime after 1977, which is believed to have directly caused the population's extirpation (Appendix I).

After the Woondum site was destroyed, the species was predominantly collected at three locations where it were locally abundant: just east of Caboolture near Ningi, Qld (-27.071ºS, 153.031ºE) (last recorded in 1987, in GRFC); just west of Coolum Beach, Qld (-26.534ºS, 153.050ºE) (last recorded in 1988, in KJBC); and north of Port Macquarie *ca* 5 km along the road to Point Plomer, NSW (-31.388ºS, 152.920ºE) (last recorded in 2001, in JMC). These sites then had varying degrees of anthropogenic disturbance and now all have extreme levels of weed invasion or disturbance, some with

cattle grazing, but with no known current population of *A. h. inconstans*. Whereas the butterfly was known for a longer period at the site north of Port Macquarie in NSW, populations in Queensland were highly ephemeral and disappeared over a relatively short time after chance discoveries. In total, from 1976 to 2001 there are at least 230 specimens known, of which most were collected at the Woondum and north of Port Macquarie sites.

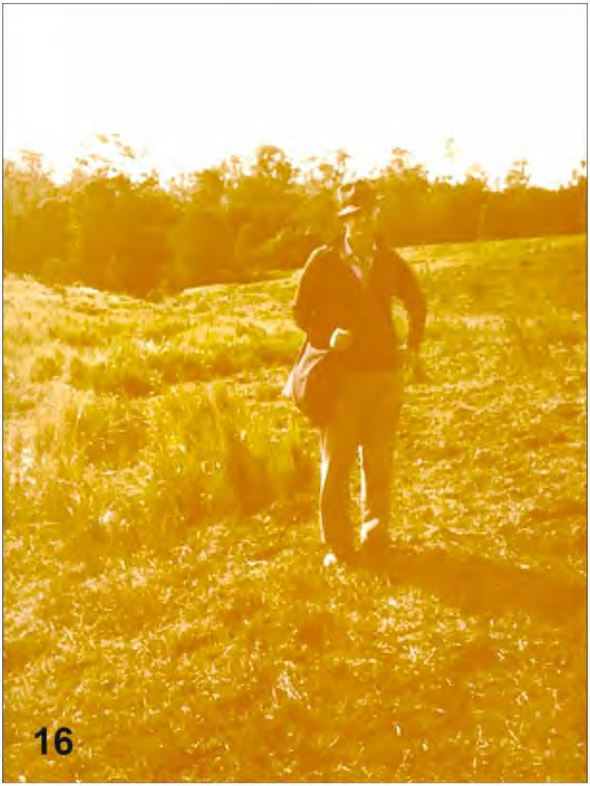
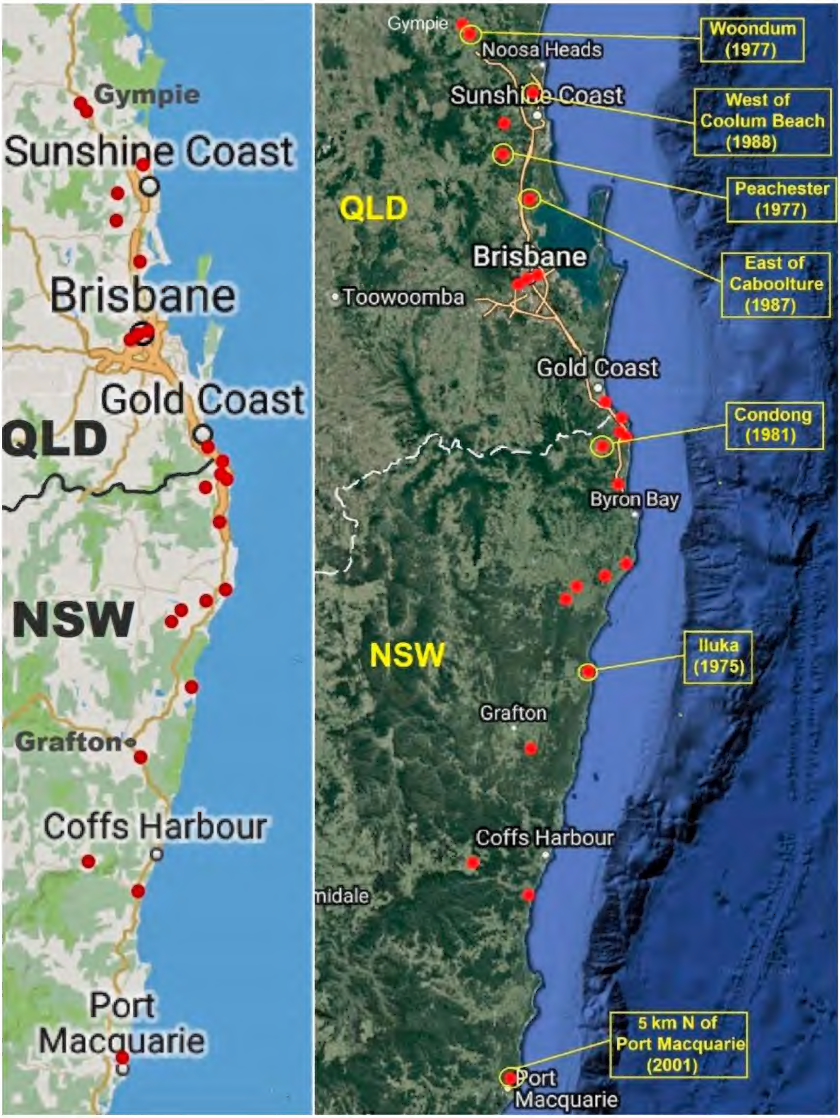


Fig. 16. Gully at Woondum (northerly aspect) in July 1977 with author's father in foreground.

All collections sites for the fritillary accepted as authentic in this study are shown in Map 1, with the name and last authenticated date of collection indicated for all sites where it has been collected since the beginning of 1975.

Literature review

The literature review (Appendix II) shows that key butterfly workers over the last 120 years have been unanimous in their evaluation of the rarity of this butterfly: Illidge in 1898 – 'an insect of extreme rarity about Brisbane';



Map 1. Central east coast of Australia showing all recorded localities for the Australian Fritillary, *Argynnis hyperbius inconstans.* Full details of all collection events with coordinates of all sites are given in Tables 1 and 2. All localities where the fritillary has been recorded since 1975 are circled in the map on the right, together with a label indicating name of locality and year the last recorded specimen was collected.

Waterhouse and Lyell in 1914 – ‘we have ourselves taken it once only’; Waterhouse in 1932 – ‘the Australian race is rare, particularly the female’; Common in 1964 – ‘rare’; Common and Waterhouse in 1972 – ‘usually rare’; Common and Waterhouse in 1981 – ‘very local, usually rare’; and Braby in 2000 – ‘is very localised…may be endangered’.

Despite early claims by Olliff (1889) that the species was ‘common in Queensland’ (Appendix II) and the subsequent perpetuation of this error predominantly until and even beyond Waterhouse and Lyell (1914), based on the literature and specimen data the species in general has been rarely encountered over the 200 or so years since Australia’s European settlement. Despite the overall paucity of data in the literature relating to *A. h. inconstans*, there seems to be a constant theme that its habitat is primarily wet locations where the host plant grows, with most of these locations being at low elevation and with the butterfly rarely encountered.

Figs 17-18. Two male specimens of exotic *Argynnis hyperbius* sold to the Department of Agriculture and Stock insect collection (now QDAFC) as *A. inconstans* by Thomas Batcheler over the period from the late 19th to the early part of the 20th Century. Both specimens were fictitiously labelled as originating from (17) Australia (dated ‘189-’) and (18) Mt Gravatt, Brisbane (dated ‘1915’).

The butterfly's rarity, even during the early days, cannot be overstated. Two male specimens, labelled 'Mt Gravatt, Brisbane' and 'Australia' (collection dates 11 November 1915 and 189? respectively), were sold to the then Department of Agriculture and Stock (now QDAF) by Thomas Batcheler, a local bird collector and taxidermist. QDAF records indicate that Batcheler sold butterflies from 1896 until the end of 1918, with some of the last entries mentioning foreign specimens (J.S. Bartlett pers. comm.). Examination of both specimens (in QDAFC: Figs 17-18) has confirmed them to be foreign and, based on their age, are more than likely to have originated from northern India, where *A. hyperbius* was predominantly known at that time.

Batcheler might have known the rarity of *A. h. inconstans* and possibly the origin of his two specimens and, consequently, could have asked a premium price for them, erroneously as Australian specimens. In addition, someone, perhaps Batcheler, was perceptive enough to provide just male specimens of *A. h. hyperbius* (*cf.* Figs 12 and 14), which can be mistaken for males of *A. h. inconstans*. Conversely, females of the two taxa are noticeably different (*cf.* Figs 13 and 15). Despite a suspicion of duplicity on the part of Batcheler, it seems that even in the early 20th Century, *A. h. inconstans* must have been a rarity and highly desirable within the butterfly collecting fraternity.

Another contemporary example of fraud associated with *A. h. inconstans* occurred in 2007, when butterflies were reportedly collected at Clontarf and in the area just east of Caboolture near Ningi, Qld (R. Kendall pers. comm.). Personal examination of several of the latter specimens (again only males purportedly collected) showed them to be exotic and a subsequent investigation of the source of the material indicated that they were purchased from a butterfly dealer and likely originated in Thailand *(i.e. A. h. hyperbius*).

Biology and distribution

Argynnis hyperbius is unique among the fritillaries in that it occurs across four biogeographic zones, *viz*. Palaearctic, Afrotropic, Indo-Malayan and Australasian (Udvardy 1975), occurring from Ethiopia eastward through India, Asia, Indonesia, New Guinea and Australia (Tuzov 2003). The type locality for *A. h. hyperbius* is Guangzhou, China, based on a female lectotype (Edwards *et al*. 2001, Tuzov 2003). As in the genus *Argynnis* Fabricius itself, the systematics of *A. hyperbius* have been rather confusing, with many described subspecies or races. The most recent summaries of its taxonomy are those of Tsukada (1985) and Tuzov (2003) who list upwards of 14 names for this species, with the most recent name proposed for a population in Timor Leste (Mendes and Bivar de Sousa 2010). Larsen (1986) considered many of these races to be inseparable.

The males of these northern subspecies are especially like those of *A. h. inconstans*. Larvae of all subspecies feed on *Viola* spp (Moore 1900, Fruhstorfer [1912], Woodhouse 1949, Wynter-Blyth 1957, Fleming 1975,

Larsen 1986, 2002, Bascombe *et al*. 1999, Ito 2001) and larvae have similar patterns and colours (Moore 1900, Bascombe *et al*. 1999, Sankowsky 2015, van der Poorten and van der Poorten 2016). Flight periods of the northern subspecies are most months of the year (Moore 1900, Ito 2001), which is the same for the Australian taxon.

What seems to mainly distinguish the Australian taxon from its northern relatives is that all the northern taxa predominantly occur in montane regions of the tropics and subtropics (between 800 and 3000 m: Moore 1900, Fruhstorfer [1912], Carpenter 1935, Woodhouse 1949, Wynter-Blyth 1957, Samson 1976, Parsons 1998, Ackery *et al*. 1995, Spitzer *et al*. 1993, Vane-Wright and de Jong 2003, Mendes and Bivar de Sousa 2010) and only at sea level in cool temperate zones (Ito 2001, Bascombe *et al*. 1999), whereas *A. h. inconstans* is almost solely known from coastal subtropical locations. In addition, the northern taxa are migratory and invade new areas (Wynter-Blyth 1957, Corbet and Pendlebury 1978, Larsen 1986), while males are known to frequently hilltop (Moore 1900, Fraser 1916, Wynter-Blyth 1957, Bascombe *et al*. 1999). Ito (2001) reported no summer or winter diapause for *A. h. hyperbius* but with a protracted development time over the colder months.

Parsons (1998) specified that *A. h. niugini* Samson, 1976 (Figs 14-15) in Papua New Guinea occurs in areas of open grassland at altitudes from 1500 to 3000 m (Samson 1976); D'Abrera (1985) and Woodhouse (1949) indicated that *A. h. neumanni* (Rothschild, 1902) in Ethiopia and *A. h. taprobana* (Moore, 1881) in Sri Lanka occur in forest margins and in open glades near forest and jungle; while Fruhstorfer [1912] reported collecting *A. h. hyperbius* on the grassy slopes of the Man-Son Mountains of China at elevations of 500-760 m.

Other than these records, the northern subspecies of *A. hyperbius* are mostly known from anthropogenically disturbed environments. This is also the case in Australia, when several of the early stages of *A. h. inconstans* and some of its biology were described by Lambkin and Lambkin (1977) from the population found in a partly grazed horse paddock at Woondum, Qld. In Hong Kong, Bascombe *et al.* (1999) recorded *A. h. hyperbius* frequently in open, sunny secondary growth and observed it commonly in lychee orchards, where its larval food plant (*V. betonicifolia*) grew abundantly. In India, Fruhstorfer [1912] reported *A. h. hyperbius* to be abundant in tea gardens 'where the wild violet thrives', and Tayyib *et al*. (2005) recorded it in cropped areas and in forest areas where weeds such as grasses and ornamental tree species had invaded. In Sri Lanka, Moore (1900) and Woodhouse (1949) recorded *A. h. taprobana* commonly in tea gardens where the *Viola* host plant grew as a weed under tea plants, or where the forest had been cleared (Woodhouse 1949). In high mountain grassland in Papua New Guinea, D.P.A. Sands (unpublished data) observed that when anthropogenic disturbances occurred in these grasslands, such as road grading, violet and

butterfly numbers proliferated then reverted to much lower densities. More recently, van der Poorten and van der Poorten (2016) indicated that *A. h. taprobana* had always been common in the mountains of Sri Lanka along edges of forests, borders of tea fields, roadsides and railway tracks, but recent changes in weeding practices have adversely affected fritillary populations. In Vietnam, Spitzer *et al*. (1993) reported that cultivated and abandoned terraced fields and forest clearings with scattered shrubs were the preferred habitats for *A. h. hyperbius*. Ito (2001) recorded the invasion of *A. h. hyperbius* into southern Japan and noted that the host plants were wild violets growing along roads in urban areas where manual weeding was the main method of reducing violets. Despite limited data on the butterfly's natural environment, there appears to be a common tendency within the *A. hyperbius* group of taxa to exploit anthropogenically disturbed environments, which provide at least temporary host plant proliferation.

Discussion

This review of observation and collection data for *A. h. inconstans* shows that prior to 1976 the butterfly was rarely seen or recorded and, despite many specimens collected over a 20-year period after 1976, its ecology and population dynamics are still poorly known.

At that time, based on the number of butterflies observed and collected at Woondum in the 1970s, perhaps the conditions there were the most suitable for the local proliferation of the butterfly. Specifically, these conditions (based on personal observations: Lambkin and Lambkin 1977) were: a gully that was continually damp; a specific degree of anthropogenic disturbance (*i.e*. grazing by horses) leaving areas of rich soil being frequently exposed; low numbers of weeds, particularly invasive grasses, in the bottom of the gully (perhaps resulting from suppression by horses); a relatively high density of *V. betonicifolia* plants, which could be essential for larval survival and were protected by stands of *L. longifolia*; and with a supply of adjacent nectar-rich flowers, in this case *C. vulgare* growing at the top of the gully and throughout the paddock. Moreover, at Woondum, butterflies were observed only to fly in sunny conditions and, based on collection data, were collected during all seasons in the months of January and May to November.

What might be the closest thing to an undisturbed environment for the butterfly was the site just west of Coolum Beach in the 1980s. This area consisted of open wallum country with an upper storey of *Melaleuca*. Perhaps, during the 1980s, the wallum area was affected by a degree of anthropogenic disturbance as it still exists today but has many more wallum understorey plants, as noted in 2007 and 2015 (Figs 19 and 20 respectively). This growth of understorey plants suggests that the wallum environment around the 1980s might have had some anthropogenic disturbance prior to discovery of the butterfly. It is not known how much habitat around this site has been lost to clearing since the last sighting of the butterfly in 1988.

Figs 19-20. Site just west of Coolum Beach: (19) in 2007 with a dense undergrowth of wallum plants 19 years after the last collection of the butterfly (note the very dry conditions that year); (20) in 2015, much the same as 2007.

The data derived from this study show that, at least since the 1950s, *A. h. inconstans* is known almost exclusively from anthropogenically disturbed, damp areas that are mostly discretely localised zones where the butterfly is at least temporarily abundant and where its host plant *V. betonicifolia* and, perhaps, *V. banksii* grows. The study at Woondum in the 1970s, especially, showed that within these localised zones it is likely that the host plant occurs in high densities, a condition necessary to sustain the level of butterfly abundance. At times in these environments, which have specialised degrees of disturbance, the butterfly can flourish following an initial proliferation of its host plant. These special conditions appear to be ephemeral; thus, almost all specimens of *A. h. inconstans* collected over the last ≈60 years strongly indicate that it is a temporary butterfly of disturbed areas. For these reasons I am here informally dubbing *A. h. inconstans* as a 'Goldilocks' butterfly, *i.e.* a butterfly requiring an ephemeral, specific anthropogenically disturbed habitat that is quite often localised, with explicit host plant density; these conditions are required in precise 'not too little and not too much' quantities.

Prior to European settlement, was the butterfly reliant on disturbed environments or did it have (and still have) a more 'natural' habitat, perhaps in wet coastal *Melaleuca* environments? But if always reliant on disturbed environments, what factors might have caused these disturbances prior to European settlement? This review has not confirmed if the butterfly is even directly associated with *Melaleuca* woodlands but, while wetlands might provide long-term, moist refuges for both host plants and *A. h. inconstans*, deforestation and the introduction of weeds and invasive grasses into these environments has significantly reduced violet numbers, particularly of *V. betonicifolia* (MacSloy 1998, Jordan 2003, T. and C. Deane pers. comm.).

Moreover, wetland environments along the coastal strip of southeastern Queensland and northeastern New South Wales have suffered significant impact from extreme levels of clearing and disturbance and are thus one of the most disturbed and fragmented habitats within the region (Curtis *et al.* 2012).

Johnson and Valentine (2012) theorised that the butterfly might exist in low densities as metapopulations within damp and swampy areas. If this is the case, nearby anthropogenic disturbances might aid the butterfly's survival, with some individuals accidentally finding these disturbed anthropogenic zones. If these zones also gave rise to a proliferation of violets, these vagrant individuals could initiate a new colony, which might thus explain the discovery of mysteriously high densities of fritillaries in discrete areas accompanied by high violet density. If the butterfly does occur in metapopulations in wetland habitats, as speculated by Johnson and Valentine (2012), the destruction of these habitats might have led to metapopulations becoming too fragmented to maintain viability.

Figs 21-22. Along the road to Point Plomer, near Limeburners Creek National Park approximately 5 km N of Port Macquarie, with much of the disturbed areas now affected by inundation of invasive grasses: (21) along the roadside; (22) what was the known fritillary site in the 1980s and 90s.

These fritillary populations appear to persist until 'Goldilocks' conditions no longer exist, perhaps due to the violets being outcompeted by invasive grasses, which seems to have affected the site on the road to Point Plomer near Limeburners Creek National Park, north of Port Macquarie (Figs 21-22). In addition, significant degrees of further anthropogenic disturbance to these 'Goldilocks' zones, such as clearing and levelling, might result in swift extirpation of fritillary populations. Such might have been the fate of the fritillary population at Woondum, where it quickly disappeared around the same time that the paddock was bulldozed. Surprisingly, at the Woondum site in 2009 and 2013 (Figs 23-24), *V. betonicifolia* still grew in relatively low densities with *L. longifolia* where the gully once was. However, in 2014 and 2017, the property was levelled again (Fig. 25-26).

Figs 23-26. The Woondum site, decades after the fritillary population was destroyed by significant anthropogenic disturbance: (23) re-establishment of the environment with *V. betonicifolia*, observed in 2009 (northerly aspect) despite dry conditions; (24) 2013 (easterly aspect); then levelling of the property again in 2014 (25) and 2017 (26).

This study has supported previous authors in their assessment of *A. h. inconstans*, *i.e*. to be rarely observed and unpredictable in its appearance. On face value, based on the temporal distribution of collection records, the butterfly seems no rarer now than in some earlier time periods. What is different now though, when compared with these earlier periods, is the current paucity of wetland environments, due to the recent systematic and widespread destruction of lowland forests and wetlands within the known range of the butterfly. This has also impacted on the survival of *V. betonicifolia*, the ecology of which is still not well understood. This loss of usable habitat and host plant might have impacted significantly on the likelihood of the reappearance of *A. h. inconstans*. Another factor that has

delayed appreciation of the butterfly's critical status has been an overall misunderstanding, by many *bona fide* butterfly workers, on how vulnerable and endangered *A. h. inconstans* truly is. For these reasons, in 2017, the New South Wales (Office of Environment and Heritage, New South Wales Government 2017) and Federal Governments elevated the butterfly's status, resulting in its national listing as Critically Endangered (Department of Environment and Energy, Australian Government 2017).

Finally, the ecology and intermittent appearance of the butterfly seem mysterious and therefore determining its key threats might not be possible at present. A formal Action Plan for its recovery would be presumptuous at this early stage. Finding evidence of the butterfly's continued existence would seem to be the most important contribution towards its survival. The data from this study have indicated that *A. h. inconstans* has a close association with its primary hostplant, the arrow-head violet *V. betonicifolia* and mostly when the host plant is in high densities. In addition, the butterfly might be adept at finding relatively small areas with dense patches of its host plant. This capacity by the butterfly to seek out these zones might well be exploited to discover areas where it still exists. This would especially be the case in areas where the butterfly has been known previously, *e.g.* at Woondum, south of Gympie, and the area about 5 km north of Port Macquarie on the road to Point Plomer (on the edge of Limeburners Creek National Park), near where areas still exist of untracked lowland country containing undisturbed forest types, including wetland areas.

Thus, it might be possible to attract females of *A. h. inconstans* to discrete areas with dense patches of *V. betonicifolia*. This strategy could entail choosing several disturbed grazing or secondary growth areas near where the butterflies were previously known. These areas could then be intentionally disturbed, while maintaining low densities of invasive weeds, sufficient to promote high densities of *V. betonicifolia* by sowing of seed and subsequent monitoring. This method of monitoring for presence of the butterfly might be more efficient in time and cost than traditional surveying, as surveys through areas of virgin forests and wetlands, including modified environments, might not detect the butterfly if it is in low densities. Moreover, traditional surveys for the butterfly and its host plant, as were conducted in 2016 at the previous fritillary site around 5 km north of Port Macquarie, failed to detect the butterfly and, furthermore, found little *V. betonicifolia* (T. and C. Deane pers. comm.), perhaps due to extensive clearing and significant weed invasion.

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Appendix I

Review of preserved specimens of *A. h. inconstans* (Table 2)

Pre-1901 (17 specimens)

The first specimens known of *A. h. inconstans* were reported by Ellis (2010), who illustrated two specimens (♂ and ♀) in a natural history collection chest made for Lachlan Macquarie, Governor of New South Wales from 1810 to 1822. The specimens were collected in New South Wales, which at that time included much of the east coast of Australia (Ellis 2010). It is unknown how widespread collections of natural history specimens made for the collectors' chest were and the exact locations where the two specimens were collected are unknown. The specimens, housed in the 'Macquarie Collectors' Chest' (Ellis 2010), were transported to Scotland in 1822 and later acquired by the SLNSW in 2004. These two specimens are clearly the earliest known, dating back before 1822, approximately 50 years before Butler (1873) described the taxon.

Other specimens likely all prior to 1901 (Table 2) are from Brisbane (1 ♂ in SAM), Gympie (1 ♂ in AM, 4 – sexes unknown in MV) and the Blackall Range (1 ♀ in QM) in Queensland and from Ballina (3 ♂♂, 1 ♀ in AM) and near Grafton (1 ♀ in AM) in New South Wales. Included here are the three type specimens in the NHM (from Moreton Bay [1 ♂] and Australia [1 ♂, 1 ♀]) which are pre-1873 (Butler 1873) (discussed in Appendix II).

1901-1940 (11 specimens)

From 1901, up to and including 1940 (Table 2), the species was collected in Queensland at Gympie in 1902 (1 ♂, 1 ♀ in AM), Brisbane in 1914 (1 ♂ in SAM), Indooroopilly in 1915 (1 ♀ in QM), Coolangatta in 1921 (1 ♀ in QM) and Burleigh Heads in 1940 (1 ♂ in ANIC) and in New South Wales at Tweed River (1 - sex unknown, KD record), Billinudgel in 1910 (1 ♂ in ANIC), Richmond River in 1910 and 1911 (2 ♂♂ in AM) and Urunga in 1920 (1 ♂ in AM). Noteworthy collections made during this period were the ♂ specimen collected at Urunga (in AM) by G.A. Waterhouse and mentioned by him in Waterhouse (1932) and a ♀ collected at Indooroopilly, Brisbane (in QM) by Ludvig (Lou) Franzen [1879-1945] in February 1916 (one of only four specimens reliably known from Brisbane, including a ♂ collected at Bulimba).

The actual collection of the female from Indooroopilly is noted by Don Franzen (De Baar and Franzen 2003), who remembered his father Clarence (Clarrie) Franzen telling him 'that at the age of 7, and in company of his father (Lou Franzen), he collected this specimen in a grassy paddock at Indooroopilly'. The mention by Moss (2003) that the species was 'common at Indooroopilly about 50 years ago' was incorrect as the specimens he referred to were those that Don Franzen collected with his father Clarence at the Woondum site, south of Gympie, in 1977.

Table 2. Summary of label data for specimens of *Argynnis hyperbius inconstans* with period of collection and place of collection. Included are year of collection (when known), number of recorded specimens collected that year and specimen depository; abbreviations of specimen depositories are outlined in the Abbreviations section above; abbreviations for collectors' names are indicated below (*).

Year of collection	Locality	Coordinates	No of specimens	Collector	Specimen depository
Pre-1822	New South Wales?		1♂, 1♀	per Macquarie	SLNSW
Pre-1873	Moreton Bay, Qld		1♂	? (Gibbons)	NHM
Pre-1873	Australia		1♂, 1♀	? (Parzudaki)	NHM
1872	Brisbane Qld	-27.47° S, 153.02° E	1♂		SAM
1893	Gympie, Qld	-26.19° S, 152.66° E	2 – sexes?		MV
1895	Gympie, Qld	-26.19° S, 152.66° E	1 – sex?		MV
1895	Glenugie Creek, Grafton, NSW	-29.782° S, 153.032° E	1♀	SWJ	AM
1896	Blackall Range, Qld	-26.69° S, 152.89° E	1♀		QM
1896	Gympie, Qld	-26.19° S, 152.66° E	1♂, 1 – sex?		AM, MV
1898	Ballina, NSW	-28.87° S, 153.56° E	3♂♂, 1♀	GAW	AM
1901	Tweed River, NSW	-28.24° S, 153.53° E	1 – sex?		KD
1902	Gympie, Qld	-26.19° S, 152.66° E	1♂, 1♀		AM
1910	Billinudgel, NSW	-28.50° S, 153.52° E	1♂		ANIC
1910	Richmond River, NSW	-28.93° S, 153.44° E	1♂	RY	AM
1911	Lauderdale, Richmond River, NSW	-28.93° S, 153.44° E	1♂	RY	AM
1914	Brisbane, Qld	-27.47° S, 153.02° E	1♂	TPL	SAM
1915	Indooroopilly, Brisbane, Qld	-27.50° S, 152.97° E	1♀	LF	QM
1920	Urunga, NSW	-30.50° S, 153.02° E	1♂	GAW	AM

1921	Coolangatta, Qld	-28.17° S, 153.54° E	1♀	Barnard	QM
1940	Burleigh Heads, Qld	-28.09° S, 153.45° E	1♂	CPL	ANIC
1958	Bora Ridge, Coraki, NSW	-29.045° S, 153.224° E	3♂♂, 1♀	NFP, BP	ANIC
1959	Coraki, NSW	-28.982° S, 153.284° E	1♂, 1♀	NFP	SAM
1960	Cudgen, NSW	-28.266° S, 153.565° E	1 – sex?	NFP	? (KD)
1960	Bora Ridge, Coraki, NSW	-29.045° S, 153.224° E	3♂♂, 2♀♀	BP	AMSC, ANIC
1965	Condong, NSW	-28.312° S, 153.434° E	1♂, 1♀	NG, SSB	SSBC, QM
1973	Dorrigo, NSW	-30.34° S, 152.71° E	1♂, 1♀		ANIC
1974	Dorrigo, NSW	-30.34° S, 152.71° E	1♀		ANIC
1975	Condong, NSW	-28.312° S, 153.434° E	1♂, 1♀	SSB, CGM	SSBC, CGMC
1975	Clarence River nr Iluka, NSW	-29.402° S, 153.350° E	1♂	GD	AM
1976	Woondum (6.5 km S of Gympie, Qld)	-26.237° S, 152.701° E	5♂♂, 1♀	DoB	DoBC
1977	Woondum, Qld	-26.237° S, 152.701° E	74♂♂, 33♀♀	TAL, MDB, GBM, DJF, CF, AJJ, CGM, IFBC, SJJ, JFRK	TALC, QDAFC, QM, CGMC, MTQ, ANIC
1977	Peachester, Qld	-26.844° S, 152.883° E	1♂	G,JAB	QM
1977	5 km N of Port Macquarie, NSW	-31.388° S, 152.920° E	1♂	AMS	AMSC
1979	5 km N of Port Macquarie	-31.388° S, 152.920° E	1 – sex?	HR	SGC
1979	E of Caboolture, Qld	-27.071° S, 153.031° E	?	DB	DBC
1980	E of Caboolture, Qld	-27.071° S, 153.031° E	?	DB	DBC

1980	5 km N of Port Macquarie	-31.388º S, 152.920º E	4 – sexes?	FGS, JB	ABR, JB, SGC
1981	Condong, NSW	-28.312º S, 153.434º E	1♀	BJ	QM
1983	E of Caboolture, Qld	-27.071º S, 153.031º E	1♀	MS	QM
1983	5 km N of Port Macquarie	-31.388º S, 152.920º E	1 – sex?	RCM	MCZ
1985	W of Coolum Beach, Qld	-26.534º S, 153.050º E	4♂♂, 2♀♀	MAT, AIK, TAL	QDAFC, SSBC, TLIKC
1985	5 km N of Port Macquarie	-31.388º S, 152.920º E	2♂♂	RPM	RPMC, CMC
1986	5 km N of Port Macquarie	-31.388º S, 152.920º E	9♂♂, 3♀♀, 3 – sexes?	AFA, MMH, SSB	AFAC, MCZ, ANIC, MV, SSBC
1986	W of Coolum Beach, Qld	-26.534º S, 153.050º E	3♂♂, 5♀♀, 6 – sexes?	AJJ, IRJ, SJJ, RGE	MTQ, WAM, MCZ, MV
1987	E of Caboolture, Qld	-27.071º S, 153.031º E	1♂, 1♀	RG	GRFC
1988	W of Coolum Beach, Qld	-26.534º S, 153.050º E	1♀	KJB	KJBC
1992	5 km N of Port Macquarie	-31.388º S, 152.920º E	6♂♂, 1 – sex?	RPM	RPMC, MV
1993	5 km N of Port Macquarie	-31.388º S, 152.920º E	2♂♂	RPM	RPMC
1994	5 km N of Port Macquarie	-31.388º S, 152.920º E	2♂♂, 2♀♀, 1 – sex?	RGE, RPM, LM	MCZ, RPMC, LMC, GSC
2001	5 km N of Port Macquarie	-31.388º S, 152.920º E	1♂	JM	JMC

* AFA – A.F. Atkins, AIK – A.I. Knight, AJJ – A.J. Johnson, AMS – A.M. Sundholm, BJ – B. Johnstone, BP – B. Purkiss, CF – C. Franzen, CGM – C.G. Miller, CPL – C.P. Ledward, DB – D. Bell, DJF – D.J. Franzen, DoB – D. Binns, FGS – F.G Sattler, GAW – G.A. Waterhouse, G,JAB – Graham, J.A. Baker, GBM – G.B. Monteith, GD – G. Daniels, HR – H. Ross, IFBC – I.F.B. Common, IRJ – I.R. Johnson, JB – J. Brooks, JFRK – J.F.R. Kerr, JM – J. Moss, KD - K. Dunn database, KJB – K.J. Beattie, LF – L. Franzen, LM – L. Matthews, MAT – M.A. Thomson, MDB – M. De Baar, MMH - M.M. Hunting, MS – M. Strong, NFP – N.F. Paul, NG – N. Gough, RCM – R.C. Manskie, RG – R. Gerrits, RGE – R.E. Eastwood, RPM – R.P. Mayo, RY – R. Young, SJJ – S.J. Johnson, SSB – S.S. Brown, SWJ – S.W. Jackson, TAL – T.A. Lambkin, TPL – T.P. Lucas, WBB – W.B. Barnard.

1941-1957 (no specimens)

There are no collections recorded for *A. h. inconstans* from 1941 up until 1958.

1958-1975 (20 specimens)

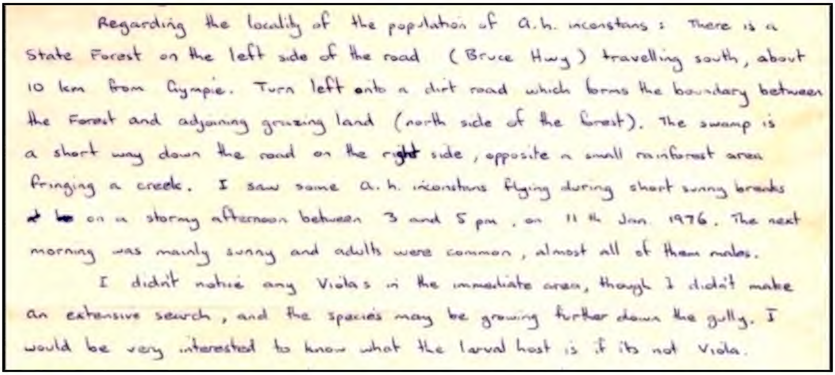
Over the 17 years from 1958 up to and including 1975 (Table 2), the 20 specimens known are all from New South Wales: Bora Ridge in 1958 and 1960 (5 ♂♂, 2 ♀ in ANIC, 1 ♂, 1 ♀ in AMSC), Coraki in 1959 (1 ♂, 1 ♀ in SAM), Cudgen in 1960 (1 – sex unknown in ANIC), Condong in 1965 (1 ♂ in QM, 1 ♀ in SSBC) and 1975 (1 ♂ in SSBC, 1 ♀ in CGMC), Dorrigo in 1973 and 1974 (1 ♂, 2 ♀♀ in ANIC) and Iluka in 1975 (1 ♂ in AM). The 11 specimens from Bora Ridge and Coraki, NSW, were collected by N.F. Paul and B. Purkiss. A.M. Sundholm from Sydney, who knew Paul, noted that Paul and Purkiss were teachers at the Bora Ridge Public School over this period and, prior to his passing, Paul donated his only two remaining Bora Ridge specimens to Sundholm (now in AMSC) (♀, Fig. 13). Additionally, Lance Matthews from Ballina recalled speaking with Harvey Leadbeater from Pimlico, Ballina, who had several fritillaries collected from swampland near Bungawalbin, about 10 km south of Bora Ridge. Matthews also noted that Leadbeater collected some of his specimens around the same time as those of Paul and Purkiss, along drains running beside teatree plantations at Coraki. Unfortunately, these specimens are believed to no longer exist but this area appears to have been a fritillary 'hotspot' over those few years.

Worth noting over this period is the collection of 1 ♂ and 2 ♀♀ (all in ANIC) at Dorrigo, NSW, in December 1973 and April 1974. Dorrigo is the highest location (750 m) recorded for *A. h. inconstans*, with almost all other specimens known from locations close to sea level. Other collections during this period were made at Condong in northern NSW, predominantly around sugar cane plantations in 1965 and 1975. A ♂ (in QM) from Condong, NSW, was collected in March 1965 by the late N. Gough (Entomological Society of Queensland 2016), who spent 1965 in Condong under a cadetship for the Colonial Sugar Refining Company (now CSR). In the late 1970s he advised the author that *A. h. inconstans* was very common in 1965, flying up and down the drains that ran parallel to the sugarcane plots. He described the butterflies as 'plentiful' and found larvae, which he reared to adults, on the violets that grew on the slopes of the drains. No fritillaries remain in his collection, still held by his family in Brisbane. It is suspected that due to his interest in trading butterflies with a fritillary expert in California in the 1960s, he likely traded the specimens for North American *Speyeria* species (North American Greater Fritillaries). Gough's trading of butterflies was possibly initiated by his North American contact, who would have known the rarity of the Australian taxon. Gough told the author in 1978 that, at that time, he was unaware of the rarity of the taxon and the unique situation that he had discovered. S.S. Brown from Bowral, NSW also collected a ♀ in January

1965 near the Condong sugar mill (SSBC). In January and November 1975 two more specimens, 1 ♂ and 1 ♀, were collected at this locality by Brown (SSBC) and C.G. Miller, then from Lismore, NSW (CGMC), respectively.

1976-2001 (>230 specimens)

The period following 1975 (Table 2) saw a significant turnaround for the species, with the remarkable discovery of a colony in a gully in a horse paddock at Woondum, [6.25 km south of Gympie CBD], on 12 January 1976 by D. Binns, then from Hobart, Tasmania (Binns 1976). My recent communication with Binns has confirmed that he 'simply came across the Keefton Road site in 1976 whilst out collecting'. On that original day, he collected 5 ♂♂ and 1 ♀ (DoBC) and reported the butterfly to be 'relatively common' (Binns 1976). Immediately after the reporting of this discovery in November of the same year (Binns 1976), I contacted Binns and received more accurate details of the location (Fig. 27). Based on this information, I visited the site several times in January, June and July 1977 (Fig. 16), collected material (10 ♂♂ and 7 ♀♀, in TLIKC) and discovered the butterfly's life history, the host plant being *V. betonicifolia*, which grew in the gully (Lambkin and Lambkin 1977). At that time, I searched several adjacent gullies for *A. h. inconstans* but found none.



Regarding the locality of the population of A.h. inconstans: There is a State Forest on the left side of the road (Bruce Hwy) travelling south, about 10 km from Gympie. Turn left onto a dirt road which forms the boundary between the Forest and adjoining grazing land (north side of the forest). The swamp is a short way down the road on the right side, opposite a small rainforest area fringing a creek. I saw some A.h. inconstans flying during short sunny breaks on a stormy afternoon between 3 and 5 pm, on 11th Jan 1976. The next morning was mainly sunny and adults were common, almost all of them males.

I didn't notice any Violas in the immediate area, though I didn't make an extensive search, and the species may be growing further down the gully. I would be very interested to know what the larval host is if its not Viola.

Fig. 27. Excerpt of letter from Doug Binns to the author, dated 30 December 1976, providing more precise details of the fritillary site at Keefton Road, Woondum, indicated as 'about 10 km south of Gympie'. In fact, the site is 6.25 km south of Gympie CBD.

Following the discovery, the site was visited throughout 1977 by many of the butterfly workers of that time, as most had previously never seen *A. h. inconstans*: I.F.B. Common (August), M. De Baar (May and August), C. Franzen (June and July), D. Franzen (June), S.J. Johnson (August), J.F.R. Kerr (June and November), T.A. Lambkin, C.G. Miller (August and September), G.B. Monteith (June) and D. Bell (for G. Sankowsky) (*ca* 79 ♂♂

and 34 ♀♀: Table 2). The last recorded specimens from Woondum were those collected by Kerr in November 1977 (2 ♂♂, 2 ♀♀, now in ANIC). In addition to those collected in the field, G. Sankowsky reared a substantial number from eggs laid by confining a fecund, field collected female with sprigs of *V. betonicifolia* in a plastic bag. Some of these specimens were subsequently distributed to S.S. Brown (SSBC), A.N. Burns (now in MV) and F.G. Sattler (now in SGC). The number of butterfly workers of that time who visited the Woondum site attested to just how unique and special the butterfly and this site were. Sometime after November 1977, the gully at the site was levelled by a bulldozer, which is believed to have extirpated the fritillary colony.

In 1977, G. Sankowsky managed to start a free-flying breeding colony in his garden at Mt Tamborine, Qld from the female collected from this Woondum stock and maintained it until 1979, after which the colony mysteriously dispersed over a relatively short period from the property (G. Sankowsky pers. comm.). No specimens have since been observed on Mt Tamborine.

On 8 October 1977, 1 ♂ was collected at Peachester, Qld (in QM, collector as 'Graham, J.A. Baker'). On 6 November 1977, Sundholm collected 1 ♂ (AMSC) sitting on a fence post close to the road to Point Plomer, approximately 5 km N of Port Macquarie, NSW (Sundholm 1978). Four more specimens (sexes unknown) were collected between December 1979 and April 1980 at about the same location by H. Ross in 1979 (SGC) and F.G. Sattler (SGC) and J. Brooks (JBC, ABRC) in 1980 (Dunn and Dunn 1991). Another specimen (sex unknown) was collected by R.C. Manskie at the same location in April 1983 (in MCZ).

At Condong, NSW on 1 December 1981, a ♀ was collected flying along a drain near a sugarcane field (Johnston and Johnston 1984). This ♀ (now in QM), was induced to oviposit when confined with *V. betonicifolia* and some of the specimens reared from those eggs were lodged in ANIC and QM. Johnston and Johnston (1984) failed to rear a subsequent generation and released two pairs of butterflies at the original collection site. No further specimens have been observed at Condong.

In southeastern Queensland, just east of Caboolture, D. Bell collected several specimens (exact number unknown) on the Caboolture to Bribie Island road in August and September 1979 and in January 1980 (DBC). The butterflies were observed flying up and down a side road adjacent to a pine plantation, feeding on small flowers and, within the plantation, feeding at *Lantana camara* L. (Verbenaceae) blossom. One of these, a fecund female, was confined over *V. betonicifolia* and induced to oviposit and these eggs were sent to G. Sankowsky who, by then, had moved to Tolga in northern Qld. Progeny from these eggs were subsequently reared through several generations in his garden at Tolga, after which the population, much like his previous population at Mt Tamborine, emigrated quickly and disappeared.

Colour photographs of its life history and the progeny he reared from the Bribie Island road eggs were subsequently used in Sankowsky (2015). Near the same location along the Caboolture to Bribie Island Road, on 4 March 1983, M. Strong of the Abbey Museum, Ningi retrieved a ♀ (now in QM) from a spider's web on the grounds of the museum. In October and November 1987, R. Gerrits, then of Brisbane, collected a further two specimens, 1 ♂ and 1 ♀ respectively (now in GRFC), just west of the Abbey Museum. Strong recalled that sometime after his collection of the specimen in the spider's web, he was contacted by a butterfly collector (he could not recall his name) who, together with Strong, found a population of the butterfly in a very restricted area of the adjacent pine forest. They also found immatures of the butterfly on *V. betonicifolia* growing under lantana, with the butterflies being very common in this small location. This section of the pine forest has since been cleared for cattle grazing.

In Queensland in February 1985, M.A. Thomson (then of the Queensland Department of Forestry) collected 2 ♂♂ (QDAFC) in a *Melaleuca* swamp close to Coolum Beach, behind the Sunshine Coast, on the left-hand side of the Coolum Beach to Yandina Road. In March 1985, this area was sparsely vegetated and inundated with water and fritillaries were observed and collected flying over water (TAL, AIK unpublished data). It was noted at the time that there were large areas of cleared forest close by on the other side of the road. It is unclear if the butterflies were breeding in the *Melaleuca* area or in anthropogenically disturbed areas nearby. Over the following three years this site was visited by several collectors: K.J. Beattie (1 ♀ in KJBC), R.G. Eastwood (1 – sex unknown in MV, 4 – sexes unknown in RGEC, now MCZ), S.J. Johnson and I.R. Johnson (3 ♂♂, 5 ♀♀ in MTQ, 1 – sex unknown in WAM), A.I. Knight (2 ♂♂ in SSBC), T.A. Lambkin (2 ♀♀ in TLIKC), with the last of these collections made by Beattie in March 1988 (Table 2). Since this last date, regular visits to the site have been made by several butterfly workers (Beattie, I.R. Johnson, Lambkin and Wilson) without success. Relatively few specimens were collected from the site (*ca* 21 specimens recorded including the 2 ♂♂ of Thomson), due in part to the overall much lower numbers observed compared with the Woondum site and to the successful rearing of progeny by several collectors (by confining females over *V. betonicifolia*). These additional (reared) specimens were lodged in several collections (at least 30 recorded specimens). It is unknown when the population was extirpated or vanished, or whether advancing sugarcane plantations or nearby extensive land clearing at that time reduced the viable area for the butterfly. The collections made by Beattie on 14 March 1988 (who also reared several specimens from a captive female) remain the last specimens of *A. h. inconstans* known from Queensland.

During the mid-1980s, many specimens were collected approximately 5 km north of Port Macquarie. A.F. Atkins (pers. comm.), previously from Newcastle, informed me that in 1985 an amateur collector, who lived in

Newcastle (near Lake Macquarie), asked him to identify butterflies he had collected approximately 5 km north of Port Macquarie over the Easter period of 1984. The collector showed him 'about 20 or so near perfect fritillaries all caught, I think on the same day'. Atkins visited the same site in January 1986 and collected 10 ♂♂, 2 ♀♀ and 1 – sex unknown and reared another ♀ from an egg collected in the field (in AFAC).

Atkins advised that he saw many fritillaries flying and collected all his material, on one day, in a cleared grassy area with small swampy ponds, visited by grazing cattle from an adjacent paddock. The site was about a kilometre north of the cluster of houses on the landward side of the Point Plomer road, *i.e.* roughly 5 km north of Port Macquarie. This area was bordered on its northern side by wet *Melaleuca* country with a small creek. Interestingly, Atkins described to the author how he observed females of *A. h. inconstans* around the ponds and under the *Melaleuca* trees, alighting onto the ground and walking over plants of *Viola banksii*. Adult butterflies were also observed feeding at blossom of *Lantana camara* growing alongside the road heading north to Point Plomer. The single egg that he did have time to collect had been laid on a defoliated violet stalk that he assumed was also *V. banksii*. He saw very little *V. betonicifolia* in the immediate area but *V. banksii* was very common. Atkins also brought several live females back to Newcastle that laid eggs readily when confined with *V. odorata* L. (a naturalised species native to Europe and Asia). The larvae readily accepted *V. odorata* but unfortunately, because he lacked an adequate supply of the host plant, cannibalism was high and he managed to rear just 1 ♀ through on this host. Johnston and Johnston (1984) also reported that these two latter violets were used to feed larvae of *A. h. inconstans* when their supply of *V. betonicifolia* was exhausted.

Near this same site, R.P. Mayo, then of Sydney, collected six more specimens (4 ♂♂, 1 ♀, 1 – sex unknown) in January and April 1985 and in March 1986 (all in RPMC). In January 1986, M.M. Hunting collected another three specimens (sexes unknown) (MV, ANIC, MCZ), while S.S. Brown collected a ♂ in January 1986 and another ♂ in January 1987 (SSBC).

In the 1990s, A. Moore of Port Macquarie collected 1 ♂ in February 1992 (ASMC); Mayo collected another seven (6 ♂♂ and 1 – sex unknown) in April 1992, 2 ♂♂ in April 1993 and, finally, 3 ♂♂ in April and May 1994 (including 1 ♂ reared ex larva) (all in RPMC). In addition, from a female collected by Mayo and confined over a potted *V. betonicifolia*, he reared several more specimens that emerged in June and July 1994. Additionally, in May 1994, L. Matthews of Ballina visited a location approximately 5 km north of Port Macquarie. This location consisted of a cleared paddock being grazed by cattle with *V. betonicifolia* growing within remnant bunches of *L. longifolia*. It is unclear if this was the same site where Atkins collected his specimens a decade earlier but, by the descriptions of Atkins and Matthews,

the locations might have been at least near each other; however, the site now was impacted more by grazing cattle. Matthews only collected 2 ♀♀ out of only three observed on that day (1 ♀ in LMC, 1 ♀ in GSC), in addition to a final instar larva. He subsequently confined one female over potted *V. betonicifolia*, from which he reared several specimens that emerged in June and July 1994 (LMC); these specimens were lodged in several other collections. In June 1994, R.G Eastwood reared one specimen (sex unknown) from the same general area (RGEC in MCZ). The last known fritillary observed was a ♂ (Figs 12, 28) collected by J. Moss of Brisbane (JMC) on 17 April 2001, about 5 km north of Port Macquarie, on the ocean side of the road as it landed on a thistle flower (J. Moss pers. comm.). Since 2001, there have been several unsubstantiated sightings of *A. h. inconstans* in this area.

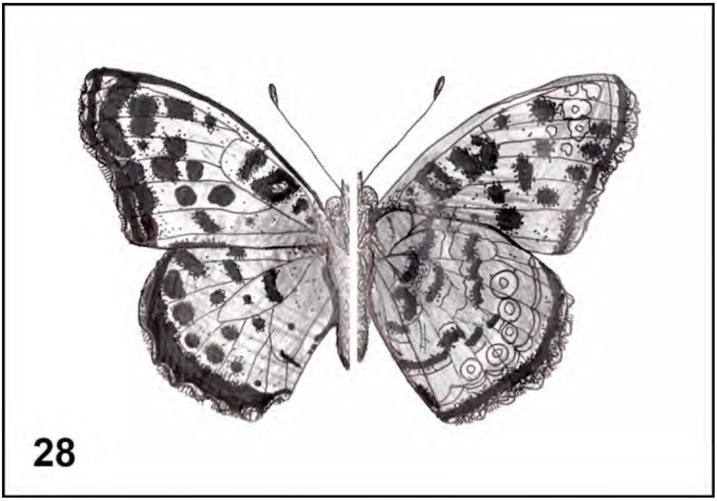


Fig. 28. Male *A. h. inconstans*: the last known specimen collected (by J. Moss), 5 km N of Port Macquarie NSW, on 17 April 2001 (JMC); LHS upperside, RHS underside. Ink pen drawing A.A. Davies, Brisbane.

Appendix II

Literature review of *A. h. inconstans*

1873-1899

The first reference to *A. h. inconstans* was its description at species rank in 1873 by Arthur Gardiner Butler [1844-1925]. Butler noted differences between females of *A. inconstans* and *A. hyperbius*, listed collection sites as 'Moreton Bay' (1 ♂) and 'Australia' (1 ♂, 1 ♀), without collection dates and cited the collectors or sources of his specimens as 'Gibbons' and 'Parzudaki' respectively. Émile Parzudaki operated a bird dealership in Paris in the mid-19th century (Steinheimer 2005) and, like Butler, was a bird enthusiast. He likely sold these early specimens of *A. inconstans* to the British Museum (NHM), a common practice for museums in the 19th century (Moulds 1999). Nothing is known of the source labelled 'Gibbons' but it is possible that this specimen (labelled 'Moreton Bay') was supplied by Silvester Diggles [1817-1880], who sent insect specimens to the NHM at that time (Marks 1963). 'Moreton Bay' was the name used in the early- to mid-1800s for the settlement later named Brisbane and was where Diggles resided. Subsequently, Kirby (1877) included *A. inconstans* in his catalogue, with 'Australia' as its location.

Around the same time that Butler (1873) described *A. inconstans*, George Masters [1837-1912], who was then the Assistant Curator at the Australian Museum (AM) in Sydney (Stanbury and Holland 1988), published his 'Catalogue of the described diurnal Lepidoptera of Australia' (1873) and listed *A. inconstans* (as *A. niphe*) from Queensland and New South Wales. He was evidently unaware of Butler's description as he referred to *A. inconstans* as *A. niphe* (the name by which *A. hyperbius* was previously known). There is a male specimen in the SAM labelled 'Brisbane, Queensland', dated 1872. This specimen might have been collected by Rowland Illidge [1846-1929], who was guided in natural history by the older Diggles, both of whom lived in Brisbane around that time (Mackerras and Marks 1974). The butterflies collected by Illidge went via T.P. Lucas [1843-1917] to the SAM (Mackerras and Marks 1974). Thus, based on this early date, this specimen perhaps could be Masters' Queensland record.

I have not found any specimen that represents the New South Wales record. Masters produced his 1873 catalogue while at the AM, before being appointed as curator of the Macleay Museum collection in Sydney in 1874. The missing specimen from 'New South Wales' could have been at the AM and subsequently taken by Masters to the MM but, if so, it is not there now (E. Jefferys pers. comm.). Herbison-Evans and Crossley (2016) illustrated Macleay Museum fritillaries and indicated that the female shown is exotic. However, the male they show on *Lantana* blossom is also not Australian.

Argynnis h. inconstans next appeared in the literature in a collection of butterflies made by E.J. Cairn and R. Grant at Mt Bellenden-Ker, just south

of Cairns (Olliff 1888). In this paper, Arthur Sidney Olliff [1865-1895] reported the collection of 27 butterfly species, including *A. h. inconstans*, from the mountain or 'in the vicinity'. The only specimen in existence from northern Queensland is a ♂ specimen in the SAM labelled 'Cairns' with no collection date. If this is indeed the specimen from the Bellenden-Ker area, one wonders how it ended up in the SAM, since Cairn and Grant collected specifically for the Australian Museum. It is pertinent to point out that, *contra* Olliff (1888), Cairn and Grant (1890), in their own account of their Bellenden-Ker visit, did not include the fritillary in the butterflies they listed. Also, the prodigious Lepidoptera collector Frederick Parkhurst Dodd [1861-1936] never recorded fritillaries from the Cairns region, although he lived there for 30 years from 1906 when the environment was relatively undisturbed (Monteith 1991). For these reasons the 'Cairns' record of *H. h. inconstans* is not accepted in this work.

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Fig. 29. First illustration of *Argynnis inconstans* (*A. h. inconstans*), a male, in 'Australian Butterflies: a brief account of the native families' (1889) by A.S. Olliff.

In 1889, Olliff produced a small booklet entitled 'Australian Butterflies: a brief account of the native families', published by the Natural History Association of New South Wales. It gave a brief description of *A. h. inconstans*, illustrating the species for the first time – a male (Fig. 29). He also commented that it was 'common in Queensland' and 'is sometimes seen as far south as the Hunter River'. Apart from the pre-1873 Moreton Bay type in NHM, I located only two labelled extant Queensland specimens of *A. h. inconstans* known in Australia from around the time that Olliff wrote his work in 1889 (1 ♂ Brisbane 1872 and 1 ♂ 'Cairns', SAM). One of these, perhaps the 'Cairns' specimen, was likely the male illustrated in Olliff's (1889) publication. Since only two extant specimens are known in Australia

from that time, it is apparent that during this period the species was not 'common in Queensland' as indicated by Olliff (1889).

Considering the few specimens known prior to 1890 and the lack of published information, it is highly likely that Olliff, newly arrived in Australia (Moulds 1999), had no firsthand knowledge of the butterfly. Furthermore, as *A. h. inconstans* and its northern relative *A. h. hyperbius* bear a superficial resemblance, particularly in flight, to the danaines *Danaus chrysippus* (Linnaeus, 1758) and *D. petilia* (Stöll, 1790) (Lepidoptera: Nymphalidae) (Butler 1873, Kirby 1877, Moore 1900, Woodhouse 1949, Wynter-Blyth 1957, Binns 1976, Bascombe *et al*. 1999), it might be that records provided to Olliff were the result of confusion between *D. petilia* and *A. h. inconstans*. Olliff might have taken these records on face value, having no idea that *A. h. inconstans* was so rarely observed.

Moreover, Olliff (1889) indicated that the butterfly's range extended to the Hunter River, New South Wales. Prior to Olliff's arrival in Australia, Alexander Walker Scott [1800-1883], a naturalist and talented artist, lived on Ash Island on the lower Hunter River near Newcastle and, together with his two daughters, painted several life histories of Australian butterflies and moths, which were first published in 1864 (Scott 1864). The two daughters subsequently donated insect specimens to the Australian Museum. There is a reference to *A. h. inconstans* (as *Arginnis inconstans*) in the Scott's specimen register in the AM, but there are no specimens from Ash Island there. A.W. Scott's insect collection comprised specimens collected locally and further afield than Ash Island; these latter specimens were sent to Scott from other contacts and collectors (Dory 2013). Thus, as no Ash Island specimens of *A. h. inconstans* exist, with doubt over the origin of their registry list record and the fact that Waterhouse never mentioned the Hunter River location again from 1914 onwards, it seems probable that the Hunter River (Ash Island) record of Olliff (1889) is incorrect.

William Henry Miskin [1842-1913] published his 'Catalogue of Australian Butterflies' in 1891, maintaining Olliff's questionable information in listing 'Hunter River' as a location for *A. h. inconstans* and repeating Masters' (1873) locations of 'New South Wales' and 'Queensland', but added 'Brisbane' and 'Nerang River' as Queensland localities. At that time, Miskin was a member of the Queensland Museum (QM) Board of Trustees and there are several specimens of *A. h. inconstans* in the QM without label data (5 ♂♂ and 2 ♀♀) that appear to be pre-1901. Due to his association with the QM (Monteith and Mather 1986) and, as I cannot find a specimen labelled 'Nerang River' in the QM collection, or elsewhere, at least one of these unlabelled specimens might be Miskin's 'Nerang River' record; the others are possibly from 'Brisbane'. Soon after Miskin's (1891) catalogue appeared, Kirby (1896) published his second work on 'Lepidoptera of the World', in which he referred to *A. inconstans* from Australia being an allied form of

A. niphe but 'differing from *A. niphe* in that the female of *A. inconstans* resembled the male' (essentially the same information as in Butler (1873)).

Just before the turn of the century, Rowland Illidge [1850-1929] published a 'List of Butterflies of the Brisbane District' (Illidge 1898), describing *A. h. inconstans* as 'an insect of extreme rarity about Brisbane' and noting that he knew of only 'one or two specimens having been taken'. Perhaps Illidge's words were the first accurate account of the 'rarity' of *A. h. inconstans*. We know Illidge had close personal experience of the fritillary because he lived in the Brisbane suburb of Bulimba, then a low-lying, swampy area beside the Brisbane River, and one of his specimens is labelled 'Bulimba'.

1900-1932

Moore (1900), in his work 'Lepidoptera Indica', made a direct comparison of *A. h. inconstans* (as *Acidalia inconstans*) from Australia with *A. castetsi* (as *Acidalia castetsi* Oberthür, 1889) from southern India. He commented that the females of *inconstans* and *castetsi* were the only two taxa in the *A. hyperbius* group that lacked the distinctive purple ground colour and the white band of the forewing upperside, although females of some populations of *A. h. castetsi* possess only a faint white forewing band (Bingham 1905).

Five years after Illidge (1898) published his list of Brisbane butterflies, Gustavus Athol Waterhouse [1877-1950] published his 'Catalogue of Rhopalocera of Australia' (Waterhouse 1903). In this catalogue, he updated taxonomic information and amended the known distributions of many species, although for *A. h. inconstans* he repeated the 'Hunter River' locality of Olliff (1889) but extended the distribution from the Hunter River in New South Wales to Rockhampton, Queensland. Records of extant specimens of *A. h. inconstans* indicate that in the early 20th century, when Waterhouse published his catalogue, there were, and still are, no specimens known north of Gympie, Qld (apart from the 1 ♂ purportedly from Cairns) and, at that time, none known south of Grafton, NSW. The origin of the Rockhampton reference is a mystery. Moreover, Waterhouse, in all his later publications, never again referred to *A. h. inconstans* occurring north of Gympie or at the 'Hunter River' and therefore the veracity of these two localities is doubtful. Furthermore, Waterhouse, during the first decade of the 20th Century, was in contact with two collectors residing in the Rockhampton area (E.P. Jones and Miskin), who made no reference to collecting *A. h. inconstans* at Rockhampton (Waterhouse and Lyell 1914).

In 1907, William Rainbow [1856–1919] published his 'Guide to the study of Australian Butterflies' (Rainbow 1907), in which he repeated Waterhouse's (1903) information on the butterfly's distribution ('Hunter River' to 'Rockhampton') and even reiterated the wording of Olliff (1889), *i.e.* 'common in Queensland' and 'is sometimes seen as far south as the Hunter River'. In that same year, Walter Froggatt [1858-1937] published his

'Australian Insects' (Froggatt 1907), mentioning *A. h. inconstans* and again repeating the words of Olliff (1889), *i.e*. 'the species has been recorded as far south as Hunter River, N. S. Wales'. He further stated that 'it is common along the cleared tracks in the Queensland jungle', despite there being no records of *A. h. inconstans* being either common or occurring in rainforest.

As part of Adalbert Seitz's 'Macrolepidoptera of the World: a systematic account of all the known Macrolepidoptera', Hans Fruhstorfer [1866-1922] reviewed the '*hyperbius*' group (Fruhstorfer [1912]) and lowered the status of *A. inconstans* to a subspecies of *A. hyperbius*, remarkably basing this on the male only and stating that he had not seen a female. He cited *A. h. inconstans* as being found in Australia, again quoting the earlier purported distribution indicated by Olliff (1889) and Waterhouse (1903) as 'Hunter River as far as Rockhampton', but added that 'they are exceedingly rare in Continental collections'.

In 1914, Waterhouse collaborated with George Lyell [1866-1951] to produce 'Butterflies of Australia' (Waterhouse and Lyell 1914), a significant taxonomic monograph on all the then known species and subspecies of Australian butterflies. They reviewed the then current knowledge of *A. h. inconstans* and the distribution and temporal data they presented matched very closely extant museum specimens known up to that time (in AM, SAM and MV). Based on these records, they indicated a much more restricted range for the species than that previously reported. Thus, only Gympie, Brisbane and Richmond River (Ballina) were noted as collection sites, with the months of capture being January-March. They illustrated a male specimen from Gympie and commented that they had only collected one specimen up to that time, at the 'mouth of the Richmond River'.

About 10 years after the publication of 'Butterflies of Australia', Burns and Thorn (1924) reported capturing this species, with Waterhouse, at Richmond River, NSW, very close to Ballina. They mentioned two possible collection sites: 'North Creek Road' and 'South Beach', both 'some five miles from Ballina'. The next report was by Waterhouse (1932) in 'What Butterfly is that?' Waterhouse recorded a male collected at Urunga, at the mouth of the Bellinger River, NSW, thereby extending its southern distribution [Waterhouse (1932) cited only Brisbane, Gympie and Richmond River as other sites]. In addition, he noted that the species is 'always about damp places' and mentioned that he collected his Urunga specimen in a swamp. Thus, the only collections recorded between the publication of Waterhouse's two books (*i.e*. between 1914 and 1932), are his at Urunga and Burns and Thorn's at Richmond River. Furthermore, the Urunga specimen collected by Waterhouse, in October 1920 (AM), was only the fifth collected by him over a span of 22 years, commencing in 1898 (AM). Lastly, Waterhouse (1932) reiterated its rarity (particularly the female) and mentioned life history observations made by Illidge, with the larval host plant as wild violets.

1933-1980

Roughly 20 years after 'What Butterfly is that?' appeared, Charles Barrett [1879-1959] and Burns published 'Butterflies of Australia and New Guinea' (Barrett and Burns 1951). Although more 'popular' than scientific, the authors did include *A. h. inconstans*, giving its distribution as from the Bellinger River, NSW (Waterhouse's Urunga locality) to Gympie, Qld, reiterating Waterhouse's (1932) statements that it is 'a rare butterfly in Australia', 'is found only near sea level' and 'frequents swampy places'. Barrett and Burns (1951) noted that most specimens had been collected from the mouth of the Richmond River, NSW and near Cooroy, Qld. Their Cooroy location is puzzling as they indicated that 'most specimens had been taken there' but there are no known specimens from Cooroy.

The 1960s saw the publication of the first 'pocket guide' on Australian butterflies by Ian Common [1917-2006]. Common (1964) published the first photograph (in monochrome) of *A. h. inconstans*, a female incorrectly referred to as a male. Common essentially repeated Waterhouse's (1932) information, giving its distribution as 'Gympie to Urunga' and reiterating that it was 'rare' and was found in 'damp places' with larvae occurring on 'wild violets'.

During the early 1970s, three major books addressed the Australian butterfly fauna. In 1971, Charles McCubbin [1930-2010] published 'Australian Butterflies' and again essentially repeated the information from Waterhouse (1932), giving the months of capture as January, February, March, July, August and November, these derived from Waterhouse and Lyell (1914), Waterhouse (1932) and AM specimens. Also in 1971, Bernard d'Abrera [1940-2017] published his 'Butterflies of the Australian Region', essentially an illustrated catalogue. Regarding *A. h. inconstans*, D'Abrera (1971) repeated the information in Common (1964) and, in addition, stated that the distribution of *A. h. inconstans* also included 'New Guinea and Papua', further indicating that 'specimens taken in New Guinea appear to belong to this race'. Nonetheless, despite the overall paucity of information provided by D'Abrera (1971) and his error concerning the taxon's distribution, he did illustrate the first colour photographs of the male and female. A year later, 'Butterflies of Australia' by Common and Waterhouse (1972) essentially replaced 'What Butterfly is that? (1932). Although Common and Waterhouse (1972) providing extensive updated information on most Australian butterflies, they provided nothing new regarding *A. h. inconstans*.

The 1970s were significant for *A. h. inconstans*, as several specimens were collected in January 1976 from a swampy gully at Keefton Road, Woondum, [6.25 km south of Gympie CBD], Qld'. Binns (1976) reported that adult butterflies were 'relatively common' at this site, had a 'slow fluttering flight', 'males being much more numerous than females' and the adults in flight showed 'some resemblance to *Danaus petilia*'.

Subsequently, Lambkin and Lambkin (1977) received information about the locality from Binns (Fig. 27) and, from this, discovered the immature stages of *A. h. inconstans* in January 1977 and described the life history (including monochrome photographs) for the first time. Larvae were collected from *Viola betonicifolia* growing among long-leaved mat rush (*Lomandra longifolia*) and blady grass (*Imperata* sp.: Poaceae) growing in a gully within a horse paddock opposite the 'swampy gully' mentioned by Binns. Adult butterflies were reported flying in the paddock and feeding on spear thistle (*Cirsium vulgare*) and continued to be observed commonly in January 1977 and from April through to November the same year (Lambkin and Lambkin 1977, TAL unpublished data), prior to the site's destruction.

Additionally, in November 1977 a male was collected in coastal swampland alongside the road to Point Plomer, approximately 5 km north of Port Macquarie, NSW (Sundholm 1978), which extended the known range 100 km south of Urunga. A search was undertaken near the collection site but no further specimens were discovered (Sundholm 1978).

1981-2000

In 1981, Common and Waterhouse published a revised edition of 'Butterflies of Australia'; their updated information on the distribution, ecology and life history of *A. h. inconstans* was derived almost entirely from the then recent data of Binns (1976), Lambkin and Lambkin (1977) and Sundholm (1978).

Johnston and Johnston (1984) reported the capture of a single female of *A. h. inconstans* near cane fields at Condong, NSW in December 1981 and the captive rearing of progeny on *V. betonicifolia* at Birkdale, Qld from her eggs. They provided information additional to Lambkin and Lambkin (1977) on its life history and reported an equal sex ratio in reared individuals, but failed to rear a second generation from caged pairs. They also reported larvae successfully feeding on *V. banksii* and *V. odorata*.

The 1991 'Review of Australian butterflies: distribution, life history and taxonomy' by Kelvyn and L.E. Dunn was a synthesis of collection data aimed at presenting the status of each Australian butterfly taxon as known at that time, predominately sourced from contributed records from public and some private collections. In their review, Dunn and Dunn (1991) commented on *A. h. inconstans*, predominately sourcing information from Johnston and Johnston (1984), specimens from several collections and personal communications from several collectors; they also indicated that the species was likely endangered in Australia.

By the mid-1990s, it was becoming apparent to some butterfly workers that *A. h. inconstans* might be threatened. This view was based on the paucity of recent collection records, the overall lack of known resident populations and the widespread destruction of lowland habitats, plus an overall lack of understanding of its mysterious appearances and the identity of its habitat.

In the late 1990s, the Butterfly and other Invertebrates Club (BOIC, based in Brisbane, Qld) provided some background information on the fritillary and planned an interim recovery and action plan for it (Anon. 1997, 1998, Jordan 1999a, b, 2002, Moss 2000). Government funding was anticipated to supplement the project but financial support was never achieved. Despite its best attempts during this time, in their Issues Paper (Anon. 1997) the club provided many unsubstantiated recordings for the butterfly in 1983, 1992 and 1994 in the Caboolture area. From these years only one specimen exists, collected in 1983 (QM) just west of Ningi. Other unverified statements were also published (Anon. 1997) on the abundance of the butterfly being dependant on natural firing of grasses and a high water table, where violets grow close to *Casuarina* and *Melaleuca*, despite providing no ecological data to support these statements. However, the club did determine that *V. betonicifolia* had largely disappeared over the previous decade or so from the Brisbane area (MacSloy 1998, Jordan 2003).

Sands (1999) briefly mentioned *A. h. inconstans* and suggested that recovery actions for the species might be difficult due to the overall destruction of the species' wet habitats within its range. He perpetuated the error of Olliff (1898) in saying that the species was 'once common', quoting Rainbow (1907) who had repeated the words of Olliff. However, Sands (1999) did point out that the species was then believed to be endangered.

In 2000, Michael Braby summarised the published information on *A. h. inconstans* in 'Butterflies of Australia – their identification, biology and distribution', predominately sourcing Binns (1976), Lambkin and Lambkin (1977), Johnston and Johnston (1984) and Sundholm (1978). In addition, Braby (2000) cast doubt on the authenticity of the two historical distribution records of Rockhampton (Olliff 1889) and Hunter River (Rainbow 1907) and highlighted the need for protection of remaining populations of the butterfly, which he considered to be endangered due to its restricted geographical range and the existence of very few populations within this range.

2001-2016

The following year, Edwards *et al*. (2001) indicated that the likely type locality of *A. h. inconstans* was Moreton Bay, Queensland. In 2002, Sands and New undertook an extensive overview of the conservation requirements for all Australian butterflies, resulting in their publication 'Action plan for Australian butterflies' (Sands and New 2002). This publication resulted from communications with butterfly experts across Australia. Sands and New (2002) ranked relative degrees of conservation status for many of Australia's butterfly species; for *A. h. inconstans* they presented a treatment of its likely habitat, possible threatening processes and its level of data deficiency. Their overview, however, included several errors – several collection dates were inaccurate but, more importantly, the last collection dates given for *A. h. inconstans* in New South Wales and Queensland were incorrect.

For example, in Queensland the Woondum site just south of Gympie, originally discovered by Binns (1976) (Lambkin and Lambkin 1977), was destroyed shortly after 1977 (G. Sankowsky and M. De Baar pers. comms). This was thought to be responsible for the extirpation of the fritillary population there, 17 years prior to the 1994 date indicated by Sands and New (2002). Also, at the site just west of Coolum Beach there were no further specimens observed or collected after 1988 (K.J. Beattie, I.R. Johnson, S.J. Johnson and P.R. Wilson pers. comms), not 1995 as specified by Sands and New (2002). Furthermore, just east of Caboolture the only records of fritillaries are of several collected *ca* 1980 by D. Bell of Brisbane (DBC), one ♂ (QM) collected in 1983 by M. Strong of the Abbey Museum of Art and Archaeology, Ningi and a pair collected by R. Gerritts (GRFC) in 1987 from a localised colony along the edge of pine forest near the museum (T. Deane, G.R. Forbes, G. Gerritts and M. Strong pers. comms), not 2001 as indicated by Sands and New (2002). In addition, Sands and New (2002) placed a degree of relevance on unconfirmed observation records and the unsubstantiated pre-Waterhouse and Lyell (1914) distribution records of Olliff (1888, 1889) and Rainbow (1907). Ultimately, Sands and New (2002) and New and Sands (2004) assigned the species as 'Data Deficient' and 'Vulnerable' only in Queensland, not in New South Wales.

In 2004, 'The Complete Field Guide to the Butterflies of Australia' (Braby 2004) was published. The information provided on *A. h. inconstans* was a concise synthesis of the information published in Braby (2000) but did note its status as 'Vulnerable', as per Sands and New (2002) and indicated that its 'range has contracted significantly through habitat loss'.

Sands and New (2008) briefly discussed the enigmatic appearance and disappearance of the butterfly, based primarily on evidence since the 1970s. They reiterated that the mechanisms governing these fluctuations are not well understood, if at all, and used a rough analogy comparing a possible drought-induced larval diapause of *A. h. inconstans* to a cold-induced larval diapause in fritillaries in the northern hemisphere.

In 2010, Albert Orr and Roger Kitching produced 'The Butterflies of Australia'. This book, somewhat in the vein of McCubbin's (1971) publication with hand-painted illustrations of almost all the Australian species, also included illustrations of many host plants and immature stages. Like McCubbin (1971), Orr and Kitching (2010) illustrated, through paintings, all butterfly species in life-like poses but also included paintings of most species in 'set specimen' poses. In their discussion of *A. h. inconstans*, they highlighted that the species was 'probably Australia's most endangered butterfly'. They provided similar information to that already published regarding its habitat and behaviour and suggested that 'urban development and agricultural vandalism' were responsible for its demise in many of its previously known localities. Despite offering no new information on the

species, Orr and Kitching (2010) postulated that the only extant populations remaining might be near Limeburners Creek National Park, which is near the previous known fritillary sites approximately 5 km north of Port Macquarie.

Johnson and Valentine (2012) gave an overview of the threatened status of *A. h. inconstans*, indicating that it was considered 'Endangered' in New South Wales. They again reiterated the paucity of information on the taxon's ecology and questioned whether its juvenile stages undergo diapause. Moreover, the authors indicated that butterfly populations in previously known locations might already have disappeared and that well-known sites such as the three in southern Queensland – south of Gympie, west of Coolum Beach and east of Caboolture – had not experienced rejuvenation after suffering significant environmental disturbance. They considered the primary reason for this to be habitat destruction. In addition, the authors indicated some strategies for future recovery programs for the butterfly, including conducting extensive surveys for the butterfly and its host plant and, if found, conducting ecological studies to determine possible metapopulation parameters and determine the butterfly and its host plant's major threatening processes.

'All about Butterflies of Australia' by Sankowsky (2015) provided the first high quality colour photographs of the early stages of *A. h. inconstans*, including photographs of live adults. These photographs were from livestock collected near Caboolture, Qld *ca* 1980 from a female collected by Bell and sent to Sankowsky in Tolga (G. Sankowsky pers. comm.). Sankowsky (2015) stated that the preferred habitat is in moist gullies and coastal swamps, noting that it is 'an extremely rare butterfly' and 'Very few people have actually seen this butterfly in the wild'.

Lastly, Braby (2016) published his second edition of 'The Complete Field Guide to Butterflies of Australia', in which he provided no new information on *A. h. inconstans* and stated that habitat loss was a reason for its apparent range contraction. Braby (2016) provided a small distribution map for the taxon and this map implied that the only extant populations were those of Gympie and near Limeburners Creek National Park north of Port Macquarie. However, he did affirm that the seasonal history of the Australian Fritillary was poorly understood and thought that the butterfly in Queensland should be classified as 'Endangered'.

A REVIEW OF THE INDO-AUSTRALIAN SUBGENUS *PARATRIDACUS* SHIRAKI OF *BACTROCERA* MACQUART (DIPTERA: TEPHRITIDAE: DACINAE)

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Abstract

Subgenus *Paratridacus* Shiraki (= *Hemisurstylus* Drew, **syn. n.**) of *Bactrocera* Macquart is reviewed and 6 species included: *B.* (*P.*) *expandens* (Walker), *B.* (*P.*) *garciniae* Bezzi, *B.* (*P.*) *melania* (Hardy & Adachi), *B.* (*P.*) *melanoscutata* Drew, *B.* (*P.*) *yayeyamana* (Matsumura) and, provisionally, *B.* (*P.*) *icelus* (Hardy). Known host plants are species of *Garcinia* (Clusiaceae). A key to species is included.

Introduction

This is the eighth in a series of papers reviewing the subgenera of the economically important fruit fly genus *Bactrocera* Macquart, made possible by the revisions of Australasian and Southeast Asian species by Drew (1989) and Drew and Romig (2013) respectively. This paper deals with subgenera *Hemisurstylus* Drew and *Paratridacus* Shiraki, which are considered here to be synonymous and to contain six described species. *Paratridacus* is distinguished by a broadly rounded posterior surstylus lobe and absence of the pecten on abdominal tergite III in males, the presence of 2 pairs of scutellar setae and elongate lateral postsutural yellow vittae. It is distributed from eastern and southern Asia to Papua New Guinea and Australia and is placed in the *Melanodacus* group of subgenera as defined by Drew (1989). Known host plants are *Garcinia* spp (Clusiaceae) and no species has been attracted to known male lures. Five additional species from Papua New Guinea and Maluku, included by Drew (1989) or Drew and Romig (2013, 2016), were transferred to other subgenera by Hancock and Drew (2016, 2017b).

Genus *Bactrocera* Macquart

Subgenus *Paratridacus* Shiraki

Paratridacus Shiraki, 1933: 109. Type species *Dacus yayeyamanus* Matsumura, 1916, by original designation.

Bactrocera (*Hemisurstylus*) Drew, 1989: 13. Type species *Bactrocera melanoscutata* Drew, 1989, by original designation; **syn. n.**

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus produced but relatively short and broad (Fig. 1); pecten of cilia absent on abdominal tergite III of male; postpronotal setae absent; supra-alar setae present; prescutellar acrostichal setae present or absent; two pairs of scutellar setae; scutum with medial postsutural yellow vitta absent and lateral postsutural yellow vittae elongate.

Response to male lures. None known for any member of the subgenus.

Host plants. Recorded from the fruit of *Garcinia* spp (Clusiaceae).

Included species. *Bactrocera* (*P.*) *expandens* (Walker), *B.* (*P.*) *garciniae* Bezzi, *B.* (*P.*) *melania* (Hardy & Adachi), *B.* (*P.*) *melanoscutata* Drew and *B.* (*P.*) *yayeyamana* (Matsumura) plus, provisionally, *B.* (*P.*) *icelus* (Hardy).

Comments. The combination of a shallow emargination to sternite V and relatively long posterior surstylus lobes place this subgenus in the *Zeugodacus* group of subgenera as defined by Drew (1989). However, the posterior surstylus lobes are shorter and much broader than the narrow, elongate lobes seen in the latter group and are directed posteriorly rather than posteroventrally (Hardy 1974 and Fig. 1); *Paratridacus* therefore appears to be better placed in the *Melanodacus* group. Molecular evidence (Krosch *et al.* 2012) also indicates that at least the *expandens* complex (which includes the type-species) belongs in the *Melanodacus* group. It differs from other *Melanodacus* group subgenera in the combination of male pecten absent, prescutellar acrostichal setae present, 2 pairs of scutellar setae, anatergite mostly yellow and scutum with long, parallel-sided postsutural lateral yellow vittae present and medial vitta absent.

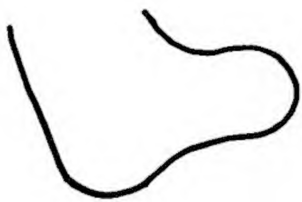

Fig. 1. *Bactrocera* (*Paratridacus*) *expandens* (Walker); male surstylus lobes.

Subgenus *Hemisurstylus* Drew shares all the defining characters of *Paratridacus* except for the lack of prescutellar acrostichal setae (a known homoplasious character of little value in classification: White 1999) and is placed here in synonymy. The shape of the posterior surstylus lobe is especially indicative of a close relationship, supported by the lack of the abdominal pecten and medial postsutural vitta, presence of 2 pairs of scutellar setae and its *Garcinia* host plant.

Five previously included species (*B. alampeta* Drew, *B. atrisetosa* (Perkins), *B. papuaensis* (Malloch) [= *B. unichromata* Drew], *B. banneri* White and *B. coracina* (Drew)) were transferred to *Austrodacus* Perkins or *Perkinsidacus* Hancock & Drew by Hancock and Drew (2016, 2017b).

Included species

Wing with costal band broad, reaching vein R_{4+5} and often broadly crossing it apically; legs with femora largely fulvous with apices often darkened;

abdomen largely fulvous or with a dark medial vitta; aculeus (where known) apically trilobed, with a pair of short lateral and a long medial lobe, all acute. Five species: Japan and Sri Lanka to Papua New Guinea and Australia. For detailed morphological descriptions and illustrations see Drew (1989) and Drew and Romig (2013).

B. (*Paratridacus*) *expandens* (Walker)

Dacus expandens Walker, 1859: 114. Type locality Aru I., Moluccas, Indonesia.

Bactrocera (*Paratridacus*) *expandens* (Walker): Drew 1989: 198; Drew and Romig 2013: 239.

Distribution. Eastern Indonesia (Aru Island), Papua New Guinea (East and West Sepik Provinces) and northeastern Australia (Queensland, as far south as Cairns).

Host plants. Garcinia dulcis (Roxb.) Kurz, *G. gibbsiae* S. Moore, *G. mangostana* Linn. and *G. xanthochymus* Hook. f. ex. T. Anderson (Drew 1989, Hancock *et al.* 2000).

Comments. Formerly regarded as widespread due to previous synonymies but restricted to the Australasian Region by Drew and Romig (2013).

B. (*Paratridacus*) *garciniae* Bezzi

Bactrocera garciniae Bezzi, 1913: 97. Type locality Peradeniya, Sri Lanka.

Bactrocera (*Paratridacus*) *garciniae* Bezzi: Tsuruta *et al*. 1997: 152; Drew and Romig 2013: 238.

Distribution. Sri Lanka and southern India (David and Ramani 2011).

Host plant. Garcinia xanthochymus (Tsuruta *et al*. 1997).

Comments. Often regarded as a synonym of *B*. (*P*.) *expandens* but shown to be distinct by Drew and Romig (2013).

B. (*Paratridacus*) *melania* (Hardy & Adachi)

Dacus expandens ssp. *melanius* Hardy & Adachi, 1954: 157. Type locality Singapore.

Dacus (*Zeugodacus*) *aptatus* Hardy, 1973: 57. Type locality Phu Kae, Thailand. Syn. Drew and Romig 2013: 240.

Bactrocera (*Paratridacus*) *melanius* (Hardy & Adachi): Drew and Romig 2013: 240.

Distribution. China (Yunnan), Thailand, West Malaysia, Singapore and Indonesia (Java); also Andaman Islands (David and Ramani 2011, as *B. expandens*).

Host plants. Garcinia dulcis and *G. xanthochymus* (Drew and Romig 2013).

Comments. Often regarded as a synonym of *B*. (*P*.) *expandens* or *B. (P.) garciniae* but shown to be distinct by Drew and Romig (2013). The name '*melanius*' was used in an adjectival sense by Hardy and Adachi (1954) and thus changes to '*melania*' when treated under *Bactrocera*.

B. (*Paratridacus*) *melanoscutata* Drew

Bactrocera (*Hemisurstylus*) *melanoscutata* Drew, 1989: 178. Type locality Kerevat, New Britain, Papua New Guinea.

Distribution. Papua New Guinea (New Britain).

Host plant. *Garcinia xanthochymus* (Drew 1989).

Comments. This species (Fig. 2) was distinguished by Drew (1989) by the presence of a broad dark band on the scutellum and the wing pattern; it also has broad dark lateral margins and medial vitta on the abdomen that are broadly united over most of tergites I+II. It differs from the other *Paratridacus* species in the presence of a fuscous band over R-M crossvein and lack of prescutellar acrostichal setae. For a detailed description and illustration see Drew (1989).

Fig. 2. *Bactrocera* (*Paratridacus*) *melanoscutata* Drew, holotype male (scutum largely obscured by pin). Photo by Geoff Thompson © Queensland Museum.

B. (*Paratridacus*) *yayeyamana* (Matsumura)

Dacus yayeyamanus Matsumura, 1916: 412. Type locality Yayeyama, [Kohama I.], Yaeyama Is, Japan.

Dacus (*Zeugodacus*) *katoi* Hardy, 1974: 50. Type locality La Granja, Negros I., Philippines. Syn. Drew and Romig 2013: 241.

Bactrocera (*Paratridacus*) *yayeyamanus* (Matsumura): Drew and Romig 2013: 241.

Distribution. Japan (Ryukyu Islands: Okinawa, Miyako, Ishigaki, Kohama, Iriomote), Taiwan and Philippines (Luzon, Negros) (Shiraki 1968, Tseng *et al.* 1992, Drew and Romig 2013).

Host plant. Garcinia subelliptica Merr. (Drew and Romig 2013).

Comments. Often regarded as a synonym of *B.* (*P.*) *expandens* or *B.* (*P.*) *garciniae* but shown to be distinct by Drew and Romig (2013). With reference to the type locality, there is no single Yayeyama (or Yaeyama) Island, that name referring to an island group at the southern end of the Ryukyu Arc. The type locality 'Yayeyama' actually appears to be on Kohama Island (adjacent to Iriomote, *vide* Google maps) and the original name '*yayeyamanus*' was used in an adjectival sense, thus changing to '*yayeyamana*' when treated under *Bactrocera*.

Provisionally included species

Wing with costal band narrow, just overlapping vein R_{2+3} and not broadly expanded apically; scutum with long, parallel-sided postsutural yellow vittae and black medial and submedial vittae, the latter broadening behind the suture and each connected with a black transverse band at the level of the anterior notopleural seta; anepisternal yellow stripe narrow; legs with femora fulvous; abdomen largely fulvous with brown lateral margins, a black basal band on tergite III and a black medial vitta over tergites III-V; aculeus needle-shaped, not trilobed. Known only from a single female from Luzon in the Philippines.

B. (*Paratridacus*) *icelus* (Hardy)

Dacus (*Zeugodacus*) *icelus* Hardy, 1974: 47. Type locality Muntinlupa, Luzon, Philippines.

Bactrocera (*Zeugodacus*) *icelus* (Hardy): Norrbom *et al.* 1999: 103.

Bactrocera (*Paratridacus*) *icelus* (Hardy): Drew and Romig 2013: 239.

Distribution. Philippines (Luzon).

Host plant. Unknown.

Comments. This species differs from those typical of *Paratridacus* in having a non-trilobed aculeus and confirmation of its subgeneric position must await the discovery of males. It was referred to subgenus *Paratridacus* by Drew and Romig (2013) and, since it cannot be referred confidently to any other subgenus, is retained there here.

Key to *Paratridacus* species

For an illustrated key to SE Asian species see Drew and Romig (2016).

1 Wing with R-M crossvein infuscated; scutellum with a broad dark medial vitta; prescutellar acrostichal setae absent; abdominal tergites I+II broadly fuscous, at most with a pair of submedial fulvous incursions posteriorly [Papua New Guinea (New Britain)] .... *B*. (*P*.) *melanoscutata* Drew

– Wing with R-M crossvein not infuscated; scutellum yellow, without a broad dark medial vitta; prescutellar acrostichal setae present; abdominal tergites I+II broadly fulvous, at least posteriorly 2

2 Scutum red-brown, at most with pale fuscous markings alongside lateral postsutural vittae; abdominal tergites III-V with at most narrow dark anterolateral markings on tergite III (not forming a complete band) and an isolated dark medial vitta on tergites IV-V 3

– Scutum black or with extensive fuscous to dark fuscous markings; abdominal tergites III-V with black T-shaped and lateral margins, the anterior band on tergite III complete 4

3 Wing with costal band indistinct and not broadly crossing vein R_{4+5}; scutum with lateral postsutural vittae narrowing posteriorly; all femora fulvous [Aru I. to NE Australia] .... *B*. (*P*.) *expandens* (Walker)

– Wing with costal band distinct and broadly crossing vein R_{4+5} into apical half of cell r_{4+5}; scutum with lateral postsutural vittae parallel-sided throughout; all femora with distinct fuscous markings, apically on hind femora [S. India and Sri Lanka] .... *B*. (*P*.) *garciniae* Bezzi

4 Scutum mostly black; abdominal tergite III mostly black, the anterior band very broad [S. China and Thailand to Andaman Is, Singapore and Java] .... *B*. (*P*.) *melania* (Hardy & Adachi)

– Scutum red-brown to dark fuscous with black patterning and often a medial black vitta; abdominal tergite III mostly orange-brown, the anterior band narrow 5

5 Wing with costal band confluent with vein R_{4+5} in centre of wing; anepisternal stripe broad, reaching anterior notopleural seta dorsally; apex of female aculeus trilobed [Ryukyu Is, Taiwan and Phillippines (Luzon, Negros)] .... *B*. (*P*.) *yayeyamana* (Matsumura)

– Wing with costal band overlapping vein R_{2+3} but not reaching vein R_{4+5} in centre; anepisternal stripe narrow, about as wide as notopleural lobe; apex of female aculeus needle-shaped [Philippines (Luzon)] .... …………………………………………………... *B*. (*P*.) *icelus* (Hardy)

Discussion

The five typical species of *Paratridacus* (those with a trilobed aculeus plus *B.* (*P.*) *melanoscutata*) are allopatric, occurring respectively in Sri Lanka and southern India (*B. garciniae*), southern China and Thailand to Singapore and Java (*B. melania*), southern Ryukyu Islands, Taiwan and the Philippines (*B. yayeyamana*), Aru to mainland Papua New Guinea and Australia (*B. expandens*) and New Britain (*B. melanoscutata*). The sixth species, *B. icelus* from Luzon, remains of uncertain placement and affinity, being known from a single female not available for study.

Five of the six species of *Paratridacus* are endemic to their respective biogeographic zones as recognised by Hancock and Drew (2015): one in Zone A (Indian subcontinent), three in Zone B (South-East Asia) and one in Zone D (New Britain); the sixth, *B.* (*P.*) *expandens*, is shared between Zones D (New Guinea) and E (Australia).

Additional notes

Bactrocera (*Perkinsidacus*) *coracina* (Drew) was incorrectly spelt as '*coracinus*' by Hancock and Drew (2017b); it is an adjectival name and was given the correct ending by Norrbom *et al*. (1999).

Cucurbita maxima flowers (Cucurbitaceae: pumpkin) were recorded as a larval host for *Bactrocera* (*Javadacus*) *trilineata* (Hardy) by Tsuruta *et al*. (1997); this is additional to *Coccinia grandis*, the only host plant listed by Drew and Romig (2013) and Hancock and Drew (2017a).

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A REVIEW OF THE INDO-AUSTRALIAN SUBGENUS *PARASINODACUS* DREW & ROMIG OF *BACTROCERA* MACQUART (DIPTERA: TEPHRITIDAE: DACINAE)

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Abstract

The *Bactrocera* Macquart subgenus *Parasinodacus* Drew & Romig is reviewed and 19 species recognised, including six transferred from other subgenera: *B.* (*P.*) *absoluta* (Walker) and *B.* (*P.*) *atypica* White & Evenhuis (newly transferred from *Asiadacus* Perkins), *B.* (*P.*) *abdopallescens* (Drew) and *B.* (*P.*) *perpusilla* (Drew) (formally transferred from *Sinodacus* Zia), *B.* (*P.*) *hoedi* White and *B.* (*P.*) *pura* White (newly transferred from *Zeugodacus* Hendel). A key to species is included.

Introduction

This paper reviews the largely Southeast Asian subgenus *Parasinodacus* Drew & Romig of *Bactrocera* Macquart, which is considered here to contain 19 described species distributed from India to New Caledonia, with six newly or formally transferred from other subgenera. It appears to be most closely related to the monotypic subgenera *Nesodacus* Perkins from the Philippines and *Aglaodacus* Munro from Madagascar. All three subgenera belong in the *Zeugodacus* group of subgenera as defined by Drew (1989) and are united by the presence of a single pair of scutellar setae plus lack of a medial yellow vitta on the scutum. Similar *Zeugodacus*-group subgenera with 2 pairs of scutellar setae were reviewed by Hancock and Drew (2017).

Genus *Bactrocera* Macquart

Subgenus *Parasinodacus* Drew & Romig

Parasinodacus Drew & Romig, 2013: 14. Type species *Dacus incisus* Walker, 1861, by original designation.

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus elongate and narrow; pecten of cilia present on abdominal tergite III of male; postpronotal setae absent; supra-alar setae usually present; prescutellar acrostichal setae present or absent; one pair of scutellar setae; scutum with postsutural medial yellow vitta absent.

Response to male lures. Cue lure (9 species) or no response known (10 species) (Drew 1989, Drew and Romig 2013, White and Evenhuis 1999).

Included species. *B. ablepharus* (Bezzi), *B. binoyi* Drew, *B. brevivitta* Drew & Romig, *B. cilifer* (Hendel), *B. citrifusca* Drew & Romig, *B. eurylomata* (Hardy), *B. incisa* (Walker), *B. longicaudata* (Perkins), *B. pahangiae* Drew & Romig, *B. pantabanganiae* Drew & Romig, *B. pseudocucurbitae* White, *B. vinnulus* (Hardy) and *B. waimitaliae* Drew & Romig, plus *B. abdopallescens*

(Drew) and *B. perpusilla* (Drew) (transferred from subgenus *Sinodacus* Zia), *B. absoluta* (Walker) and *B. atypica* White & Evenhuis (transferred from subgenus *Asiadacus* Perkins), *B. hoedi* White and *B. pura* White (transferred from subgenus *Zeugodacus* Hendel).

Host plants. Recorded from the fruit of Lauraceae and Melastomataceae (Drew and Romig 2013). A record from the flowers of Cucurbitaceae (Allwood *et al*. 1999) is uncertain.

Comments. The combination of a shallow emargination to sternite V and long posterior surstylus lobes places this subgenus in the *Zeugodacus* group of subgenera as defined by Drew (1989). It differs from all other subgenera in that group in the combination of only one pair of scutellar setae, pecten present and scutum with medial yellow vitta absent. It most resembles subgenus *Nesodacus* Perkins (containing the sole species *B*. (*N*.) *atrichus* (Bezzi): Drew and Romig 2013) and is possibly synonymous with it. However, although *Nesodacus* similarly has only one pair of scutellar setae and lacks prescutellar acrostichal setae and the medial vitta, it also lacks the pecten and, since these character states are all homoplasious (occurring in numerous unrelated subgenera) and its host plant is unknown, it is kept separate pending further study. It is also possibly related to the Madagascan subgenus *Aglaodacus* Munro (containing the sole species *B*. (*A*.) *nesiotes* (Munro)), with which it shares the absence of a medial yellow vitta, a well developed supernumerary lobe on the male wing and presence of the pecten plus prescutellar acrostichal and only one pair of scutellar setae. However, the male surstylus and sternite V characters have not been recorded for *B. nesiotes* [the surstylus merely noted as 'peculiar' by Munro (1984)], the wing is very broadly infuscated apically and lateral postsutural vittae are absent; hence it also is kept separate pending further study.

In three species where females are known, *B. hoedi*, *B. longicaudata* and *B. pura*, the oviscape is elongate, a little longer than tergites III-V combined.

Included species

For detailed morphological descriptions and illustrations of all but three species see Drew (1989) and Drew and Romig (2013); the remaining species were described and illustrated by White and Evenhuis (1999). Three species-groups are recognisable based on setal configuration, colour of the femora and geographical distribution. Molecular evidence (Krosch *et al*. 2012) suggests a close, monophyletic relationship between *B. cilifera, B. longicaudata* and *B. abdopallescens* (the three species tested) and independently supports the inclusion of Groups A, B and C in *Parasinodacus* as recognised by Drew and Romig (2013).

Group A: Prescutellar acrostichal setae present. Femora partly black or entirely fulvous. Southeast Asia to Papua Province, Indonesia. Seven species.

B. (*Parasinodacus*) *brevivitta* Drew & Romig

Bactrocera (*Parasinodacus*) *brevivitta* Drew & Romig, 2013: 226. Type locality Jln Kf Mimaland, West Malaysia.

Distribution. West Malaysia.

Host plant. Melastoma malabathricum (Melastomataceae) (Drew and Romig 2013).

Male lure. None known.

B. (*Parasinodacus*) *cilifer* (Hendel)

Dacus cilifer Hendel, 1912: 15. Type locality Koshun, Taiwan.

Dacus (*Zeugodacus*) *tenuifinis* Hardy, 1983: 42. Type locality Pasaman, Sumatra. Syn: Drew and Romig 2013: 227.

Bactrocera (*Parasinodacus*) *cilifera* (Hendel): Drew and Romig 2013: 227.

Distribution. China, Taiwan, Vietnam, Laos, Thailand, West Malaysia and Indonesia (Sumatra).

Host plant. A single male reared from [a sample of 41] male flowers of *Thladiantha hookeri* (Cucurbitaceae) in Thailand (Allwood *et al.* 1999) requires confirmation.

Male lure. Cue lure.

Comment. The name '*cilifer*' is treated as a noun in apposition (ICZN 1999).

B. (*Parasinodacus*) *citrifusca* Drew & Romig

Bactrocera (*Parasinodacus*) *citrifusca* Drew & Romig, 2013: 228. Type locality Bangkhuntak, Muang Samut Song Khram, Thailand.

Distribution. Central Thailand.

Host plant. None known.

Male lure. None known.

B. (*Parasinodacus*) *hoedi* White

Bactrocera (*Zeugodacus*) *hoedi* White, in White and Evenhuis, 1999: 529. Type locality Hollandia [= Jayapura], Indonesia.

Distribution. Eastern Indonesia (northern Papua Province).

Host plant. None known.

Male lure. None known.

Comments. This species is transferred from subgenus *Zeugodacus*, which differs in the presence of a postsutural medial yellow vitta (Drew and Romig 2013). Known only from the holotype female, it is provisionally included here in *Parasinodacus*. It was illustrated by White and Evenhuis (1999).

B. (*Parasinodacus*) *pahangiae* Drew & Romig

Bactrocera (*Parasinodacus*) *pahangiae* Drew & Romig, 2013: 232. Type locality nr Gap Rest House, Pahang, West Malaysia.

Distribution. West Malaysia.

Host plant. Litsea sp. (Lauraceae) (Drew and Romig 2013).

Male lure. None known.

B. (*Parasinodacus*) *pseudocucurbitae* White

Bactrocera (*Bactrocera*) *pseudocucurbitae* White, in White and Evenhuis 1999: 502. Type locality Danum Valley, Sabah, East Malaysia.

Bactrocera (*Parasinodacus*) *pseudocucurbitae* White: Drew and Romig 2013: 234.

Distribution. Thailand, Malaysia (West, Sarawak, Sabah) and Indonesia (Kalimantan, Lombok, Bali, Flores, Sumbawa).

Host plant. None known.

Male lure. Cue lure.

B. (*Parasinodacus*) *pura* White

Bactrocera (*Zeugodacus*) *pura* White, in White and Evenhuis 1999: 533. Type locality Dojo [? = Dobo, west of Jayapura], Indonesia.

Distribution. Eastern Indonesia (northern Papua Province).

Host plant. None known.

Male lure. None known.

Comments. This species is transferred from subgenus *Zeugodacus*, which differs in the presence of a postsutural medial yellow vitta (Drew and Romig 2013). Known only from the holotype female, it is provisionally included here in *Parasinodacus*. It was illustrated by White and Evenhuis (1999).

Group B: Prescutellar acrostichal setae absent. Femora partly black. South and Southeast Asia, including Philippines. Six species.

B. (*Parasinodacus*) *ablepharus* (Bezzi)

Chaetodacus ablepharus Bezzi, 1919: 422. Type locality Malinao, Tayabas, Luzon, Philippines.

Chaetodacus ablepharus var. *mindanaus* Bezzi, 1919: 422. Type locality Davao, Mindanao, Philippines. Syn: Norrbom *et al.* 1999: 98.

Bactrocera (*Parasinodacus*) *ablepharus* (Bezzi): Drew and Romig 2013: 225.

Distribution. Philippines (Luzon, Mindanao), East Malaysia (Sabah) and Vietnam.

Host plant. None known.

Male lure. None known.

B. (*Parasinodacus*) *binoyi* Drew

Bactrocera (*Sinodacus*) *binoyi* Drew, in Drew and Raghu 2002: 347. Type locality New Ambarambalan Forest, Kerala, India.

Bactrocera (*Parasinodacus*) *binoyi* Drew: Drew and Romig 2013: 226.

Distribution. Southern India.

Host plant. None known.

Male lure. Cue lure.

B. (*Parasinodacus*) *incisa* (Walker)

Dacus incisus Walker, 1861b: 323. Type locality Burma.

Dacus poonensis Kapoor, 1971: 478. Type locality Poona, India. Syn: Norrbom *et al.* 1999: 91.

Bactrocera (*Parasinodacus*) *incisa* (Walker): Drew and Romig 2013: 230.

Distribution. India (including Andaman Is), Burma, China (Yunnan), Vietnam, Thailand, West Malaysia.

Host plant. None known.

Male lure. Cue lure.

B. (*Parasinodacus*) *longicaudata* (Perkins)

Nesodacus longicaudatus Perkins, 1938: 134. Type locality Bettotan, nr Sandakan, Sabah, East Malaysia.

Bactrocera (*Parasinodacus*) *longicaudata* (Perkins): Drew and Romig 2013: 231.

Distribution. East Malaysia (Sarawak, Sabah) and Thailand.

Host plant. None known.

Male lure. Cue lure.

B. (*Parasinodacus*) *pantabanganiae* Drew & Romig

Bactrocera (*Parasinodacus*) *pantabanganiae* Drew & Romig, 2013: 233. Type locality Pantabangan, Nueva Ecija, Luzon, Philippines.

Distribution. Philippines (Luzon).

Host plant. None known.

Male lure. None known.

B. (*Parasinodacus*) *vinnulus* (Hardy)

Dacus (*Pacifodacus*) *vinnulus* Hardy, 1973: 23. Type locality Yala, Thailand.

Dacus (*Pacifodacus*) *drewi* Hardy, 1983: 29. Type locality nr Bohorok, Sumatra. Syn: Drew and Romig 2013: 235.

Bactrocera (Parasinodacus) *vinnulus* (Hardy): Drew and Romig 2013: 235.

Distribution. Southern Thailand, West Malaysia and Indonesia (Sumatra).

Host plant. None known.

Male lure. Cue lure.

Group C: Prescutellar acrostichal setae absent. Femora entirely fulvous. Sulawesi to New Caledonia. Six species.

B. (*Parasinodacus*) *abdopallescens* (Drew)

Dacus (*Asiadacus*) *abdopallescens* Drew, 1971: 31. Type locality Lumi, Sepik district, Papua New Guinea.

Bactrocera (*Sinodacus*) *abdopallescens* (Drew): Drew 1989: 201.

Bactrocera (*Parasinodacus*) *abdopallescens* (Drew): Hancock and Drew 2015: 101.

Distribution. Papua New Guinea (Central, Eastern Highlands, East Sepik, Madang, Morobe and West Sepik Provinces: Clarke *et al*. 2004) and eastern Indonesia (Papua Province: White and Evenhuis 1999).

Host plant. None known.

Male lure. Cue lure.

Comments. This species was provisionally referred to subgenus *Parasinodacus* by Hancock and Drew (2015) and is formally transferred here from subgenus *Sinodacus* Zia, which differs in the presence of a postsutural medial yellow vitta (Drew and Romig 2013).

B. (*Parasinodacus*) *absoluta* (Walker)

Dacus absolutus Walker, 1861a: 22. Type locality Seram, Moluccas, Indonesia.

Bactrocera (*Asiadacus*) *absoluta* (Walker): Norrbom *et al*. 1999: 87; Drew and Romig 2013: 29.

Distribution. Eastern Indonesia (Seram).

Host plant. None known.

Male lure. None known.

Comments. Provisionally retained in subgenus *Asiadacus* Perkins by Drew and Romig (2013, 2016) due to the absence of males for comparison, *B*. (*P*.) *absoluta* is transferred here to subgenus *Parasinodacus*. It differs from all other species currently included in *Asiadacus* in having supra-alar setae present and the postsutural medial yellow vitta absent. It appears to be most closely related to *B*. (*P*.) *eurylomata* from Sulawesi.

B. (*Parasinodacus*) *atypica* White & Evenhuis

Bactrocera (*Asiadacus*) *atypica* White & Evenhuis, 1999: 490. Type locality Wisselmeren, Moanemani, Kamo Valley, [West Papua Province], Indonesia.

Distribution. Eastern Indonesia (Paniai Lakes, West Papua Province).

Host plant. None known.

Male lure. None known.

Comments. This species is transferred from subgenus *Asiadacus*, which differs in the presence of a postsutural medial yellow vitta (Drew and Romig 2013). It differs from all other species in lacking supra-alar setae and in the very pale costal band restricted to cell r_1. It was illustrated by White and Evenhuis (1999).

B. (*Parasinodacus*) *eurylomata* (Hardy)

Dacus eurylomatus Hardy, 1982: 191. Type locality Lindu Valley, Sulawesi.

Bactrocera (*Parasinodacus*) *eurylomata* (Hardy): Drew and Romig 2013: 229.

Distribution. Eastern Indonesia (central Sulawesi).

Host plant. None known.

Male lure. None known.

B. (*Parasinodacus*) *perpusilla* (Drew)

Dacus (*Asiadacus*) *perpusilla* Drew, 1971: 42. Type locality Noumea, New Caledonia.

Bactrocera (*Sinodacus*) *perpusilla* (Drew): Drew 1989: 205.

Bactrocera (*Parasinodacus*) *perpusilla* (Drew): Hancock and Drew 2015: 101.

Distribution. New Caledonia (including Lifou and Maré Islands).

Host plant. None known.

Male lure. Cue lure.

Comments. This species was provisionally referred to subgenus *Parasinodacus* by Hancock and Drew (2015) and is formally transferred here from subgenus *Sinodacus* Zia, which differs in the presence of a postsutural medial yellow vitta (Drew and Romig 2013).

B. (*Parasinodacus*) *waimitaliae* Drew & Romig

Bactrocera (*Parasinodacus*) *waimitaliae* Drew & Romig, 2013: 236. Type locality Waimital, Seram, Moluccas, Indonesia.

Distribution. Eastern Indonesia (Seram and Ambon).

Host plant. None known.

Male lure. Cue lure.

Key to *Parasinodacus* species

For an illustrated key to SE Asian species see Drew and Romig (2016).

1 Scutum red-brown or orange-brown; femora fulvous without apical dark markings 2

– Scutum dark fuscous to black; femora often with dark apical markings .. 5

2 Postpronotal lobes yellow; postsutural lateral yellow vittae present; prescutellar acrostichal setae present; costal band narrow, not crossing vein R_{2+3} except at apex 3

– Postpronotal lobes fuscous or orange-brown; postsutural lateral yellow vittae absent; prescutellar acrostichal setae absent; costal band not as above 4

3 Postsutural lateral yellow vittae not extending anterior of suture; costal band expanded at apex over vein R_{4+5} .... *B. citrifusca* Drew & Romig

– Postsutural lateral yellow vittae extending anterior of suture as small spots; costal band not expanded at apex over vein R_{4+5} ..... *B. hoedi* White

4 Costal band broad, reaching vein R_{4+5} throughout its length and with a narrow extension over R-M crossvein; anal streak distinct; supra-alar seta present .... *B. waimitaliae* Drew & Romig

– Costal band vestigial, reduced to a pale tint in cell r_1; anal streak absent; supra-alar seta absent .... *B. atypica* White & Evenhuis

5 Postsutural lateral yellow vittae absent; presutural lateral yellow vittae triangular and connected with notopleural lobes; prescutellar acrostichal setae absent 6

– Postsutural lateral yellow vittae present; presutural lateral yellow vittae absent or small and connected with postsutural vittae but not connected with notopleural lobes; prescutellar acrostichal setae present or absent ... 7

6 Femora fulvous, without fuscous apical markings .... *B. perpusilla* (Drew)

– Femora fuscous to black over at least apical quarter .... *B. binoyi* Drew

7 Postsutural lateral yellow vittae short, reaching only about half the distance to postalar setae; prescutellar acrostichal setae present 8

– Postsutural lateral yellow vittae elongate, reaching postalar setae; prescutellar acrostichal setae present or absent 9

8 Femora broadly black apically, at least half distance on fore and mid femora; scutellum apically yellow .... *B. brevivitta* Drew & Romig

– Femora fulvous with at most slight infuscation at extreme apices; scutellum apically black .... *B. pahangiae* Drew & Romig

9 Femora fulvous without dark apical markings 10

– Femora with extensive fuscous to black apical markings 14

10 Anepisternal yellow stripe narrow, not reaching line of anterior notopleural seta .... *B. abdopallescens* (Drew)

– Anepisternal yellow stripe broad, reaching postpronotal lobe 11

11 Wing narrowly infuscated over crossveins R-M and DM-Cu; abdomen with a medial black vitta over tergites I-V ….. *B. pseudocucurbitae* White

– Wing without narrow infuscation over both crossveins R-M and DM-Cu; abdomen with medial black vitta absent or confined to tergite V 12

12 Prescutellar acrostichal setae present; wing narrowly infuscated over DM-Cu crossvein, broadest posteriorly; abdomen without fuscous lateral markings .... *B. pura* White

– Prescutellar acrostichal setae absent; wing not infuscated over DM-Cu crossvein; abdomen with fuscous lateral markings 13

13 Costal band faint, not crossing vein R_{4+5}; tergite V with a medial black vitta.. *B. absoluta* (Walker)

– Costal band broadly crossing vein R_{4+5} into cells br, r and apex of m; tergite V without a medial black vitta .... *B. eurylomata* (Hardy)

14 Costal band interrupted beyond apex of vein R_{2+3}, leaving an isolated apical spot; prescutellar acrostichal setae present .... *B. cilifer* (Hendel)

– Costal band not interrupted between apex of vein R_{2+3} and apical spot; prescutellar acrostichal setae absent 15

15 Presutural yellow spots present and connected to lateral postsutural yellow vittae 16

– Presutural yellow spots absent .... *B. ablepharus* (Bezzi)

16 Costal band broad, almost reaching vein R_{4+5} throughout its length and only weakly expanded apically; abdomen with distinct medial and lateral black vittae on tergites III-V .... *B. pantabanganiae* Drew & Romig

– Costal band narrow, not or barely overlapping vein R_{2+3} and often broadly expanded apically; abdomen without distinct medial and lateral black vittae on tergites III-V 17

17 Costal band narrow, not expanded apically and only weakly entering cell r_{4+5} at apex; face with a black band below antennal sockets .... *B. incisa* (Walker)

– Costal band broadly expanded apically into an oval spot that extends well into cell r_{4+5} apically to beyond half way to vein M; face without a black band below antennal sockets 18

[Note: Females of the Philippine species *B*. (*Nesodacus*) *atrichus* (Bezzi) will also run to this subgenus and couplet, differing in having a narrow costal band that almost reaches vein M apically, black transverse bands on abdominal tergites III, IV and often V and black ceromata on tergite V; males further differ in lacking the pecten of cilia on abdominal tergite III]

18 Abdominal tergites III-V fuscous to black with a narrow and short black medial vitta over tergites IV-V; costal band just overlapping vein R_{2+3} .... *B. vinnulus* (Hardy)

– Abdominal tergites orange-brown to red-brown without a dark medial vitta; costal band not overlapping vein R_{2+3} ...... *B. longicaudata* (Perkins)

Discussion

Parasinodacus is unusual among the *Zeugodacus* group of subgenera in that the few recorded host plants are, with one possible exception (*B. cilifera*: see above), non-cucurbitaceous. In this it resembles the *Melanodacus* and *Bactrocera* groups of subgenera and subgenus *Tetradacus* Miyake, suggesting that it is relatively primitive within the *Zeugodacus* group (as also suggested by Krosch *et al.* (2012) in their molecular cladogram). The lack of a medial yellow vitta on the scutum places it in a complex of subgenera that also includes *Aglaodacus* Munro, *Heminotodacus* Drew, *Nesodacus* Perkins, *Paradacus* Perkins and *Perkinsidacus* Hancock & Drew. No host plants are known for any of these other subgenera but it is likely that they are also non-cucurbitaceaous. Subgenera *Heminotodacus*, *Paradacus* and *Perkinsidacus*, which all have 2 pairs of scutellar setae, were reviewed by Hancock and Drew (2017).

Within *Parasinodacus*, Group A retains prescutellar acrostichal setae and is presumably plesiomorphic. Five of its seven species are distributed largely within Southeast Asia proper, as far west as Thailand and with one species, *B*. (*P*.) *pseudocurcurbitae*, extending eastwards to the Indonesian Lesser Sunda Islands. In the West Malaysian *B*. (*P*.) *brevivitta* and *B*. (*P*.) *pahangiae* the lateral postsutural vittae are short and apically narrowed; these two species likely form a species-pair. Of the remaining species, *B*. (*P*.) *citrifusca* has a pale scutum, abdomen and femora, *B*. (*P*.) *pseudocurcurbitae* has pale femora, a distinct medial vitta on abdominal tergites I-V and infuscated crossveins on the wing, while *B*. (*P*.) *cilifer* is characterised by the entirely black abdomen and interrupted costal band, leaving an isolated apical spot. In the two Papua Province species, *B*. (*P*.) *hoedi* and *B*. (*P*.) *pura*, the lateral postsutural vittae extend anterior of the suture as small spots and these also likely form a species-pair.

Group B, characterised by the loss of prescutellar acrostichal setae and at least partly fuscous or black femora, contains six species distributed from India to the Philippines and East Malaysia (Borneo). In the Indian *B*. (*P*.) *binoyi* lateral postsutural yellow vittae are absent and a triangular marking extends from the notopleural lobe alongside the suture, whereas in the non-Indian *B*. (*P*.) *ablepharus* the lateral postsutural vittae do not extend anterior to the suture; in the remaining species the lateral postsutural vittae do extend anterior of the suture as continuous yellow spots. In *B*. (*P*.) *incisa* the face has a black band below the antennal sockets and the costal band remains narrow throughout. In *B*. (*P*.) *pantabanganiae* abdominal tergites III-V have distinct black lateral margins and medial vitta and the costal band is broad with a weak apical expansion, whereas in *B*. (*P*.) *longicaudata* and *B*. (P.) *vinnulus* the abdominal patterns are different and the costal band is narrow with a broad apical expansion.

Group C, also lacking prescutellar acrostichal setae but with the femora fulvous, is the most easterly of the three groups, with six species recorded from Sulawesi to New Caledonia. The species are variable in appearance but presumably form a related group. In *B.* (*P.*) *absoluta* from Seram and *B.* (*P.*) *eurylomata* from Sulawesi the wings are relatively elongate and the costal band pale and somewhat diffuse, suggesting a species-pair relationship. In *B.* (*P.*) *waimitaliae* from southern Maluku and *B.* (*P.*) *atypica* from West Papua the scutum is pale without lateral postsutural vittae; in the New Caledonian *B.* (*P.*) *perpusilla* lateral postsutural vittae are also absent but a sutural triangle is present, the species thus resembling *B.* (*P.*) *binoyi*; while in *B.* (*P.*) *abdopallescens* from New Guinea the lateral postsutural vittae are present and extend anterior to the suture, thus, with its narrow costal band, somewhat resembling *B.* (*P.) incisa*.

Table 1 shows the distribution and percent endemicity of the 19 described *Parasinodacus* species according to the biogeographic zones recognised by Hancock and Drew (2015).

Table 1. Distribution of species in genus *Bactrocera* and subgenus *Parasinodacus* in each biogeographic zone and percent endemism in *Parasinodacus*. For a map of zones A-F see Hancock and Drew (2015).

Biogeographic Zone	**No. species of *Bactrocera***	**No. species of *Parasinodacus***	**% *Parasinodacus* endemic to Region**
(A) Indian subcontinent	81	2	50
(B) South-East Asia	225	10	80
(C) Wallacea	124	4	75
(D) New Guinea	170	4	100
(E) Australia	76	0	-
(F) South Pacific	59	1	100

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THE FIRST RECORD OF THE INTRODUCED FLEA *SPILOPSYLLUS CUNICULI* (DALE, 1878) (SIPHONAPTERA: PULICIDAE) FROM THE INVASIVE RED FOX IN AUSTRALIA, WITH A REVIEW OF THE FLEAS ASSOCIATED WITH THE RED FOX IN AUSTRALIA

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Abstract

The red fox, *Vulpes vulpes* (Linnaeus, 1758), is an introduced predator in Australia that has contributed to the decline of numerous native species. The first record of the introduced European rabbit flea, *Spilopsyllus cuniculi* (Dale, 1878), from the red fox is presented with a review of fleas associated with the red fox in Australia.

Introduction

The red fox, *Vulpes vulpes* (Linnaeus, 1758), was introduced into Australia in the 1860s and is now a widespread pest, absent only from Tasmania, northern Australia and small offshore islands (Menkhorst and Knight 2010). The introduction of the red fox was particularly devastating to medium-sized marsupials, many of which have declined significantly across their former ranges (Kinnear *et al.* 2002). Similarly, the European rabbit, *Oryctolagus cuniculus* (Linnaeus, 1758), was deliberately introduced and quickly became a pest across Australia (Menkhorst and Knight 2010). To combat this new pest the myxoma virus was proposed as a biological control agent and was later released to reduce rabbit numbers (Ratcliffe *et al.* 1952). However, the virus required a vector for transmission during the winter months, which led to the introduction of the European rabbit flea, *Spilopsyllus cuniculi* (Dale, 1878) (Sobey and Conolly 1971).

Observations

On 25 March 2016, fleas were collected from a road kill red fox in Panton Hill (37.6430°S, 145.2390°E), Victoria. They were identified using a LEICA M205C microscope and the keys provided by Dunnet and Mardon (1974). Electron micrographs were also taken of one of the specimens using a Hitachi TM3030 Tabletop Microscope (Fig. 1). Two of the fleas collected were determined to be *Spilopsyllus cuniculi*.

Discussion

Little has been published on ectoparasites of the red fox in Australia. Dunnet and Mardon (1974) recorded four species of fleas based on museum records. In addition to *Echidnophaga myrmecobii* Rothschild, 1909, *Echidnophaga perilis* Jordan, 1925, *Ctenocephalides canis* (Curtis, 1826) and *Ctenocephalides felis felis* Bouché, 1835, this record of *S. cuniculi* brings the total number of flea species associated with the red fox to five. These host-parasite records are tabulated in Table 1.

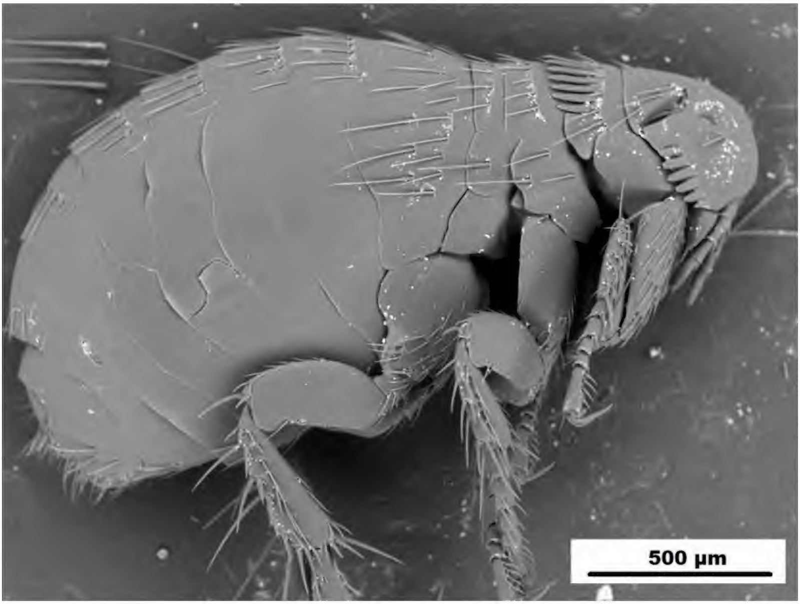

Fig. 1. Scanning electron micrograph of an adult female rabbit flea (*Spilopsyllus cuniculi*) collected from a red fox (*Vulpes vulpes*) in Panton Hill, Victoria.

Table 1. Flea species recorded from the red fox (*Vulpes vulpes*) in Australia.

Flea species	Endemic	Reference
Ctenocephalides canis (Curtis)	No	Dunnet & Mardon (1974)
Ctenocephalide felis felis Bouché	No	Dunnet & Mardon (1974)
Echidnophaga myrmecobii Rothschild	Yes	Dunnet & Mardon (1974)
Echidnophaga perilis Jordan	Yes	Dunnet & Mardon (1974)
Spilopsyllus cuniculi (Dale)	No	This paper

Echidnophaga perilis and *E. myrmecobii* are both endemic Australian fleas with wide host ranges that include many native marsupials and rodents, as well as a number of introduced species including the domestic dog, *Canis familiaris* Linnaeus, 1758 and cat, *Felis catus* Linnaeus, 1758 (Dunnet and Mardon 1974). A number of authors have recorded both flea species from the rabbit and it is possible that foxes may have come into contact with these fleas while feeding on rabbits or other native mammals infested with them (Dunnet and Mardon 1974, Shepherd and Edmonds 1978, 1979). Fleas of the family Pulicidae, to which the genus *Echidnophaga* Oliff, 1886 belongs, are of great health and environmental importance due to their ability to vector pathogens. Screening of *E. myrmecobii* for *Bartonella* sp. has thus far yielded negative results (Kaewmongkol *et al.* 2011).

Ctenocephalides felis felis and *C. canis* are introduced fleas that likely arrived with dogs or cats during early European settlement in Australia. They have been intensively studied and are linked to a wide range of pathogens and diseases in humans and animals. Both flea species are intermediate hosts for the zoonotic tapeworm *Dipylidium caninum* Linnaeus, 1758 and the filarial nematode *Acanthocheilonema reconditum* (Grassi, 1890) (Marshall 1967, Brianti *et al.* 2012). They have also been linked to the transmission of the pathogenic bacteria *Rickettsia typhi*, *Rickettsia felis* and *Bartonella henselae* (Eisen and Gage 2012). Foxes might act as wild population reservoirs from which fleas such as *C. canis* and *C. felis* are transferred to reinfest domestic dogs and cats free of flea infestations (Dryden *et al.* 1998). Šlapeta *et al.* (2011) showed that while *C. felis felis* is common, *C. canis* is extremely rare on domestic dogs and cats. This supports data presented by Dunnet and Mardon (1974) that the red fox might be a major reservoir of *C. canis* within Australia.

Spilopsyllus cuniculi is considered to be highly host specific to the rabbit (Dunnet and Mardon 1974). However, it has previously been recorded by Dunnet and Mardon (1974) from the domestic cat, based on specimens taken in Tasmania in 1973 and, more recently, by Schloderer *et al*. (2006) from specimens taken from two cats in Western Australia. The author has also viewed more than 50 specimens of *S. cuniculi* in the Victorian agricultural insect collection (VAIC), collected from the ear of a cat in Seymour, Victoria in 1986.

This new record of *S. cuniculi* from the red fox brings the total number of hosts associated with this flea species in Australia to three. However, it should be stressed that infestations on the domestic cat and red fox are usually accidental and are likely to be due to interactions these hosts have had with wild rabbits while preying on them or while in or close to rabbit warrens. It is unclear whether long term infestations of *S. cuniculi* can be maintained on either the cat or red fox. While there are few instances of disease associated with infestations of *S. cuniculi* in accidental hosts, at least two reports exist of dermatitis in domestic cats caused by *S. cuniculi* (Studdert and Arundel 1988, Harvey 1990). While no pathogens other than the introduced myxoma virus have been isolated from *S. cuniculi* within Australia, the emerging zoonotic bacterium *Bartonella alsatica* Heller *et al*., 1999 has been recorded from *S. cuniculi* in Europe (Márquez 2015). No wide-scale survey of the flea-borne bacteria present in *S. cuniculi* in Australia has been undertaken to date.

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THE FIRST RECORD OF THE NATIVE FLEA *ACANTHOPSYLLA ROTHSCHILDI* RAINBOW, 1905 (SIPHONAPTERA: PYGIOPSYLLIDAE) FROM THE ENDANGERED TASMANIAN DEVIL (*SARCOPHILUS HARRISII* BOITARD, 1841), WITH A REVIEW OF THE FLEAS ASSOCIATED WITH THE TASMANIAN DEVIL

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Abstract
The Tasmanian devil (*Sarcophilus harrisii* Boitard) is a conservation icon presently subject to intensive captive breeding efforts in an effort to prevent its extinction. The first record of infestation by the native flea *Acanthopsylla rothschildi* Rainbow is reported from a captive group of Tasmanian devils at Healesville sanctuary, Victoria.

Introduction
The Tasmanian devil (*Sarcophilus harrisii* Boitard, 1841) is a medium-sized carnivorous marsupial native to Tasmania (Menkhorst and Knight 2010). Due to the emergence of Tasmanian devil facial tumour disease in 1996, the Tasmanian devil has declined over much of its range and is now listed as endangered (McCallum 2008). As a result of its decline, captive breeding programs have been commenced to ensure its long term survival (Jones *et al*. 2007). Parasites are often greatly important to species conservation efforts and Wait *et al*. (2017) emphasised the importance of understanding the diversity and ecology of the Tasmanian devil's parasite assemblages when considering its future conservation.

Observations
Healesville sanctuary, Zoos Victoria, is one of many institutions engaged in the Tasmanian devil captive breeding program. The health of devils in this collection is closely monitored and, outside the breeding season, all adults receive monthly oral prophylactic flea treatment (Comfortis® Spinosad 270 mg chewable tablets, Eli Lilly Australia Pty Ltd). In February 2017, veterinarians from Healesville sanctuary performed a routine weaning health check on an adult female and her three joeys. Fleas were observed on all four animals, with two displaying mild clinical signs (including small papules on the ventral abdominal skin and the external pinnae of the ears and very mild alopecia on the tail dorsally). Prior to treatment of all four individuals with topical Selamectin 120 mg/ml (Revolution®, Zoetis Australia Pty Ltd), four fleas were collected from two individuals and subsequently identified by author MLK as *Acanthopsylla rothschildi* Rainbow, 1905 (Fig. 1), using the keys in Dunnet and Mardon (1974). In the absence of males, determination of subspecies was not possible.

Fig. 1. A female *Acanthopsylla rothschildi* collected from one of four infested captive Tasmanian devils (*Sarcophilus harrisii*) at Healesville Sanctuary, Victoria.

No pathological signs have been previously linked to infestations by members of the genus *Acanthopsylla* Jordan & Rothschild, 1922. However, in two of the four animals examined with infestations of *A. rothschildi*, small papules were present on the left ear and ventrum, respectively. In one of the animals slight alopecia was also noted on the dorsal surface of the tail. However, it should be stressed that causes other than flea infestation were not ruled out as contributors to these dermatological signs and there is no direct evidence that these pathological signs were caused by the *A. rothschildi* infestation.

Discussion

In an extensive review of the parasites of the Tasmanian devil, Wait *et al.* (2017) recorded the fleas *Uropsylla tasmanica* Rothschild, 1905 and *Pygiopsylla hoplia* Jordan & Rothschild, 1922 and overlooked a record of *Bradiopsylla echidnae* Denny, 1843 by Dunnet and Mardon (1974). Our record of *Acanthopsylla rothschildi* brings the number to four (Table 1).

Uropsylla tasmanica is the sole representative of the monotypic subfamily Uropsyllinae (Dunnet and Mardon 1974). It appears to be a specialist of large carnivorous marsupials and has been recorded mainly from quolls (*Dasyurus* É. Geoffroy, 1796 spp), Tasmanian devils and even the extinct Thylacine, *Thylacinus cynocephalus* (Harris, 1808) (Dunnet and Mardon 1974). It is

unique among fleas in that it is a subdermal endoparasite in its larval stage (Dunnet 1970). Pathological signs have been associated with *U. tasmanica* in carnivorous marsupials, including pustular lesions and hairlessness around the site of heavy infestations (Obendorf 1993), although mortality has not been associated.

Table 1. Flea species recorded from the Tasmanian devil (*Sarcophilus harrisii*).

Flea species	Host specific	Location recorded	Reference
Uropsylla tasmanica	No	Wild	Dunnet & Mardon (1974)
Pygiopsylla hoplia	No	Wild	Dunnet & Mardon (1974)
Bradiopsylla echidnae	No	Wild	Dunnet & Mardon (1974)
Acanthopsylla rothschildi	No	Captivity	This paper

Pygiopsylla hoplia is catholic in its host choices and has been recorded from many different families of Australian marsupials, including several members of the Dasyuridae (Dunnet and Mardon 1974). It has also been collected from Australian montremes and both native and introduced placental mammals. There have been no pathological signs directly linked to infestations by this flea.

Bradiopsylla echidnae has been recorded only once from a wild Tasmanian devil: a single female taken at Maydena, Tasmania in 1960 (Dunnet and Mardon 1974). Based on host records, *B. echidnae* appears to be extremely host specific to the short-beaked echidna (*Tachyglossus aculeatus* Shaw, 1792). Dunnet and Mardon (1974) noted that the record of *B. echidnae* on the Tasmanian devil was likely an accidental infestation. As the Tasmanian devil is known to prey upon the short-beaked echidna, it is possible that this interaction might have led to the infestation (Pemberton *et al*. 2008). Infestation of the Tasmanian devil likely occurs rarely and therefore the Tasmanian devil should be considered an accidental host for *B. echidnae*.

The genus *Acanthopsylla* is endemic to Australia and New Guinea, with many of its members exhibiting generalist host preferences (Dunnet and Mardon 1974). *Acanthopsylla rothschildi* is a common Australian species found on a range of Australian marsupials and rodents. There have been no pathological signs directly linked to previously reported infestations of this flea, although pathological signs have been recorded in wild quolls with mixed infestations of mites, ticks and fleas, including *A. rothschildi* (Vilcins *et al*. 2008). However, it is unclear what contribution, if any, *A. rothschildi* made. Given the wide host range reported for *A. rothschildi* and the fact that it has not previously been identified on Tasmanian devils, the origin of the fleas in this case is unclear. However, it is likely that they originated from wild animals, possibly small dasyurids, living within the grounds of Healesville sanctuary.

Fleas play a significant role as both vectors of disease and direct parasites of wildlife. A better understanding of the biology and ecology of the flea fauna associated with the Tasmanian devil is crucial for continued captive breeding efforts as well as reintroduction programs.

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VARIATION IN THREE KEY TAXONOMIC CHARACTERS OF WEAVER ANTS OF THE GENUS *POLYRHACHIS* (*CYRTOMYRMA*) (HYMENOPTERA: FORMICIDAE)

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Abstract

The range of variation in three key taxonomic characters (humeral angle, petiole spine length, propodeal spine length) was examined for six species of weaver ants of the genus *Polyrhachis* Fr. Smith, subgenus *Cyrtomyrma* Forel, *viz*: *P. australis* Mayr, *P. delecta* Kohout, *P. mackayi* Donisthorpe, *P. monteithi* Kohout, *P. robsoni* Kohout *and P. yorkana* Forel. The variation was recorded using score indices where 1 represented no variation and 5 represented the greatest observed variation. This was great enough in some cases to present potential problems in identification. It also raised questions of phylogenetic relationships, origin and adaptive significance.

Introduction

It has always been plain to observers that outbreeding, sexually reproducing individuals of the same species differ in their morphology, physiology and behaviour and in the way that all these traits are affected by environmental conditions and events. Naturally, this variation will apply to characters used in taxonomic keys (*e.g.* Davies 1949). A notable instance of variation in a taxonomic character among worker ants of the genus *Polyrhachis* Fr. Smith, subgenus *Cyrtomyrma* Forel, is the propodeal spine length variation in *P. yorkana* Forel (Kohout 2006, Downes 2016), where the variation itself has been used as a key character in couplet 6 of Kohout's (2006) key, separating this species from *P. abbreviata* Kohout.

Authors of taxonomic keys occasionally allow for character variation by incorporating multiple pathways. Thus, in Kohout's (2006) key to *Polyrhachis* (*Cyrtomyrma*) workers, there are dual pathways to *P. australis* Mayr and *P. yorkana*, because the pronotal humeri ('shoulders') of some individuals of these species are more toothed or more rounded than those of others (the term 'humeral angle' refers to the curvature of the shoulders and is not a quantitative measurement). In addition, a variable character can be, and normally is, noted in a species description, as it is for the shoulders of *P. robsoni* Kohout. But these measures neither claim nor guarantee that the whole range of variability (the 'norm of reaction') and sometimes even the normal range, is accommodated.

We are fortunate in having a sound taxonomic base for studies on the black weaver ants of Queensland's Wet Tropics and beyond, thanks to the work of the late Rudy Kohout. The Wet Tropics species dealt with in this paper can be found in relatively small areas with interspecifically overlapping territories and these communities can also include other black weaver ants, *viz*. *P.* (*Myrmhopla*) *mucronata* Fr. Smith and *P.* (*Myrmothrinax*) *queenslandica* Emery. Little, in most cases nothing, is known of their colony structure and

foraging habits, but they appear to form a guild, exploiting the available arboreal living space in similar ways, with different species often nesting in the same tree. The term 'black weaver ants' loosely embraces this guild of arboreal ants, with members from the subgenus *Myrma* Billberg as well as the above-named subgenera.

Methods

Numerous (>200) workers of each of five species of *Polyrhachis* (*Cyrtomyrma*) ants from Townsville (*P. australis* and *P. yorkana*) and the more northerly Wet Tropics (*P. delecta* Kohout, *P. monteithi* Kohout and *P. robsoni*) were examined to record the range of variation in humeral angle, propodeal spine length and petiole spine length. Nine *P. mackayi* Donisthorpe workers from Woolgoolga, NSW, were also examined. A value of 1 was allocated to a fully stable character and a value of 5 to a character with the greatest apparent variation. Intermediate values were given accordingly, *i.e.* the specimens themselves fixed the range across which the variation was compared.

Care was taken in all cases to ensure that the angle of view was consistent. The relative lengths and orientations of the petiolar spines were especially prone to appear different from even slightly altered angles. To overcome this, they were isolated by dissection and glued with their anterior sides orthogonal to the line of view. Mesosomas likewise were orientated such that the line of view was perpendicular to their longitudinal axes, giving a dorsal perspective to the mesosomas and their humeral angles. The sclerites comprising the 'neck', *i.e.* the joint anterior extensions of the pronotum and propleuron, were easily detached across a transverse sulcus and were lost in Figs 3, 4 and 6.

Results and discussion

Figures 1 and 2 show the shoulders of two *Polyrhachis* (*Cyrtomyrma*) worker ants from a dorsal perspective, the orientation used in the first couplet of Kohout's (2006) key to Australian *Cyrtomyrma* species. Tracking further through the key might result in an identification of *P. robsoni* for worker 1 (Fig. 1) and *P. euryala* Fr. Smith (an Indonesian species) for worker 2 (Fig. 2). It is unlikely that a collector would accept this latter determination without further evidence. Both are in fact *P. robsoni* workers, nestmates from a nest collected at Mission Beach on 18 September 2017, in which there were 42 workers displaying a wide spectrum of shoulder morphologies ranging from toothed to almost smoothly rounded.

The ranges of variation in the three characters examined, across six *Polyrhachis* (*Cyrtomyrma*) species, were in some cases at least as great as in the above example. They are summarised in Table 1 and illustrated in several cases for two of the characters discussed (Figs 3-14). For images of the propodeal spine variation in *P. yorkana*, see Downes (2016). The moderate

variation in petiole form observed in *P. mackayi* probably indicates a greater actual variation among workers of this species, considering the small sample size.

Character variation includes body size, which can differ markedly between and among the sibling cohorts from individual nests when these are the offspring of different queens. This variation is not included here but its existence is evident in some of the Figures.

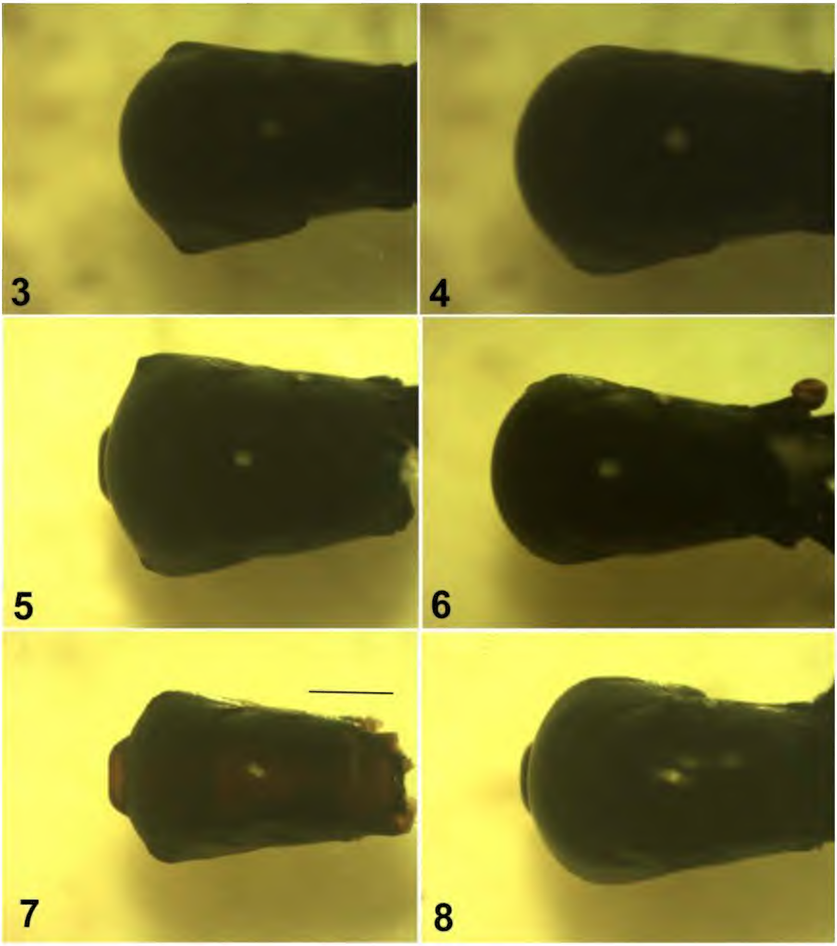
Figs 1-2. Anterior mesosoma, dorsal view showing shoulder form, of *Polyrhachis robsoni* workers 1 and 2 respectively. Photos by G. Thompson, Queensland Museum.

Table 1. Range of variation in three key taxonomic characters across six *Polyrhachis* (*Cyrtomyrma*) species. Score key: 1 = no variation; 5 = maximum observed variation. Absence of propodeal spines judged not applicable (NA), rather than not variable, for the three species concerned.

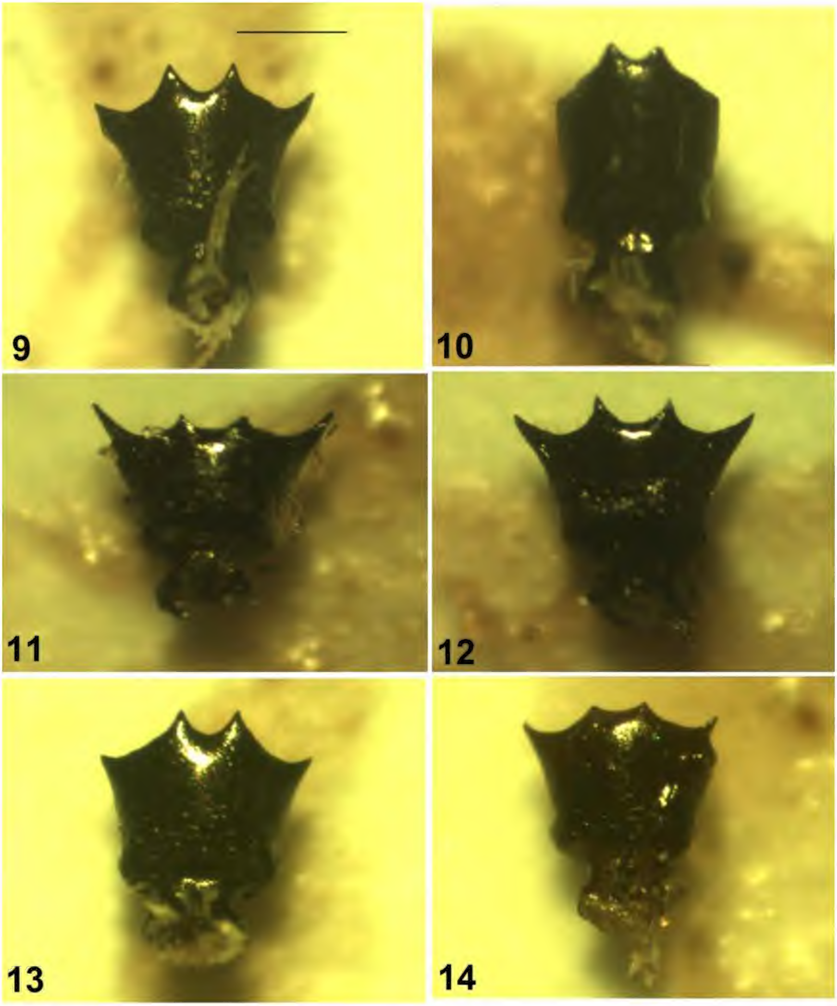
Species	Humeral angle	Propodeal spine length	Petiolar spine length
P. australis	4	1	2
P. delecta	1	NA	5
P. mackayi	1	NA	3
P. monteithi	2	2	4
P. robsoni	5	NA	2
P. yorkana	4	5	4

From a practical point of view, these variations need not necessarily hinder a correct identification because a determination is made not on the basis of an isolated character but with reference to the entire suite of relevant characters in the key or, if necessary, in the original description; or again, if an investigation warrants it, an appeal to genetic data. Kohout's (2012) remarks

about *Polyrhachis delicata* Crawley and *P. queenslandica* explicitly warn that characters of both species can be unreliable due to a high degree of variability and that, consequently 'no single character is universally diagnostic.' This would seem to be the case throughout the subgenera *Cyrtomyrma* and *Myrmothrinax* Forel and probably more widely in the genus. In general, to ensure as far as possible a correct identification, multiple data sources, if available, should be consulted (Padial *et al*. 2010, Blaimer and Fisher 2013).



Figs 3-8. Variation in humeral angle between *Polyrhachis* workers: (3-4) *P. australis*; (5-6) *P. robsoni*; (7-8) *P. yorkana*. The 0.5 mm scale bar in Fig. 7 applies to all six figures.



Figs 9-14: Variation in petiolar spine length between *Polyrhachis* workers: (9-10) *P. delecta*; (11-12) *P. monteithi*; (13-14) *P. yorkana*. The 0.2 mm scale bar in Fig. 9 applies to all six figures.

In particular, describing new species from isolated single specimens obviously requires the most stringent justification (Ma *et al*. 2014). Character variation can not only be expressed among siblings within a single nest, but also (and especially with body size) at various points along a geographical cline (Bidau and Martí 2008, Kivelä *et al*. 2011). It is unsurprising, therefore, to find that discrepancies in the body lengths of ants can be among the most

perplexing couplets in the only popular and authoritative key we have to the ant fauna of northern Queensland (Andersen 2000) where, for example, *Polyrhachis* ants of the subgenus *Hedomyrma* Forel are separated into species or species groups in part comprising those with a body length of 7 mm or more and those with a body length of 6 mm or less, leaving the many perverse individuals measuring 6.5 mm unplaced and the few more co-operative individuals at odds with the other requirement concerning how hirsute or otherwise their antennal scapes are (large ones glabrous when they should be hairy and *vice versa*).

But it isn't the potential for occasional mistakes in identification due to character variation that is of most concern or interest, its importance notwithstanding. After all, other factors, parasitism for example, can induce morphological changes that can also lead to errors in identification (Czechowski *et al*. 2007). Equally important are questions of phylogenetic relationship, origin and adaptive significance. Why did the variation in propodeal spine length arise and persist in *P. yorkana*, but not in its close congeners? Does the fact that some species have no propodeal spines at all have a bearing on this question? Why is shoulder form stable in *P. delecta* and *P. mackayi* but unstable in *P. australis*, *P. robsoni* and *P. yorkana*?

It is expected that highly stable characters are under greater selection pressures than relatively unstable characters, unless the instability itself is an adaptive trait. This is why genital characters are widely used as key characters in preference, *e.g*., to cuticular markings (Goulson 1993, Mutanen *et al*. 2007, Downes and Harvey 2016). Hence, we must suppose that in the life of *P. delecta* the role played by shoulder form actually matters more than it does in the life of *P. robsoni*. Is it an intraspecific recognition marker for *P. delecta*, in a habitat where several closely related species coexist? Unlikely, given that species and colony recognition among ants is dominated by chemical rather than visual or tactile cues. Has it something to do with the form of the nest the ants must move around in? Are any hypotheses testable and, if so, which?

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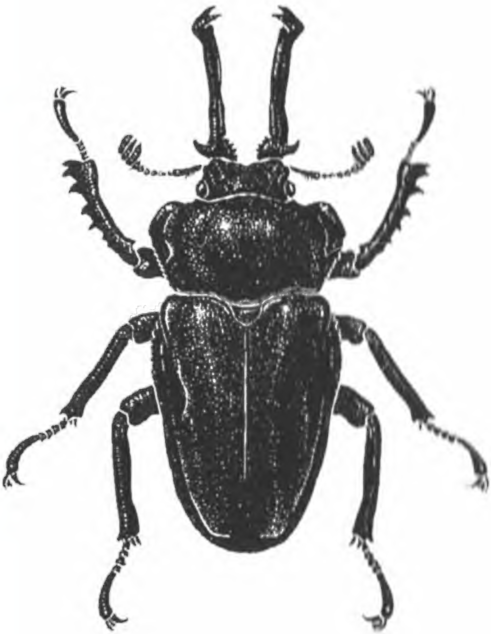

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